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AFWAL-TR-83-4033
VOLUME II

FTR450261000U

ICAM MANUFACTURING COST/DESIGN GUIDE

FINAL TECHNICAL REPORT
AIRFRAMES
USER'S MANUAL—VOLUME 2

AD B073385

PERIOD OF PERFORMANCE
1 OCTOBER 1979-31 OCTOBER 1982

JANUARY 1983

LIMITED DISTRIBUTION

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This technical report has been reviewed and is approved for publication.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFWAL-TR-83-4033 VOLUME II	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER FTR450261000U
4. TITLE (and Subtitle) ICAM "MANUFACTURING COST/DESIGN GUIDE" FINAL TECHNICAL REPORT VOLUME II - AIRFRAME MC/DG		5. TYPE OF REPORT & PERIOD COVERED Final Technical Report Vol II Oct 1, 1979 - Oct 29, 1982
		6. PERFORMING ORG. REPORT NUMBER 00035
7. AUTHOR(s) Bryan R. Noton, Principal Investigator		8. CONTRACT OR GRANT NUMBER(s) F33615-79-C-5102
9. PERFORMING ORGANIZATION NAME AND ADDRESS Battelle's Columbus Laboratories 505 King Avenue Columbus, Ohio 43201		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Project Priority 4502
11. CONTROLLING OFFICE NAME AND ADDRESS Computer Integrated Manufacturing Branch Manufacturing Technology Division (AFWAL/MLTC) AF Wright Aeronautical Laboratories Wright-Patterson AFB, Ohio 45433		12. REPORT DATE January 1983
		13. NUMBER OF PAGES 211
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Computer Aided Manufacturing	Fuselage Panels	Extrusions
Manufacturing Cost	Sheet Metal Parts	Castings
Cost Drivers	Assemblies	Forgings
Design-to-Cost	Mechanical Fastening	Test, Inspection
Airframe Design	Advanced Composites	& Evaluation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The "Manufacturing Cost/Design Guide" (MC/DG) enables airframe and electronic designers to achieve lowest cost by conducting trade-offs between manufacturing cost and other design factors. When fully developed, the MC/DG will, for example, permit airframe designers, at all levels of the design process, to quickly perform cost-trade comparisons of manufacturing processes and structural performance/cost trade-offs on airframe components and subassemblies in metallic and composite materials.

20. (Continued)

The first program, reported in AFML-TR-76-227, developed a model of the MC/DG, the contents, cost drivers, data requirements and designer-oriented formats for conventional and some emerging manufacturing technologies, and also an implementation plan.

The second program (Contract No. F33615-77-C-5027) consisted of four phases in which manufacturing man-hour data and designer-oriented formats were developed for "Sheet-Metal Aerospace Discrete Parts", "First-Level Mechanically Fastened Assemblies", and "Advanced Composite Fabrication". Further, structural performance/manufacturing cost trade-studies were conducted by designers in industry to demonstrate utilization of the manufacturing man-hour data developed in this program.

The data developed by the five participating aerospace companies were normalized by Battelle's Columbus Laboratories and the data plotted in designer-oriented formats. Data have been developed for base parts and discrete parts. The base part is a structural element in its simplest form and when modified with designer-influenced cost elements (DICE) such as joggles, cutouts, and heat treatment, a discrete part ready for assembly is obtained. Typical DICE analyzed for mechanically fastened assemblies are accessibility, material types, part and fastener counts, and sealing requirements. For composites, typical DICE are orientation and number of plies, overlaps, fiber mix, cutouts, and quality requirements.

The data are presented in the series of formats showing cost-driver effects (CDE) and cost-estimating data (CED) and have been evaluated in trade-offs on various fuselage panels designed in titanium, aluminum, and graphite/epoxy.

The third program (Contract No. F33615-79-C-5102) required the development of MC/DG sections on castings, forgings, extrusions, and test, inspection and evaluation (TI&E). Furthermore, as castings, forgings, and extrusions are normally machined prior to assembly in aerospace structures, data and formats were developed for the machining of typical discrete parts manufactured utilizing these methods. TI&E was included in the MC/DG as, in the case of certain materials such as graphite/epoxy and manufacturing methods such as castings, this can be a cost-driver that needs to be included in trade-off studies comparing various manufacturing methods.

The third program also required the development of an MC/DG for electronics fabrication, assembly, and TI&E. A series of typical discrete parts such as transistors, capacitors, diodes, and hybrids were analyzed and also, typical assemblies such as printed wiring boards. Hand, semiautomatic and automatic soldering and insertion processes were also analyzed. Furthermore, the manufacturing cost to meet typical reliability requirements in electronics is also presented to the designer for the selected discrete parts.

20. (Continued)

This project is reported in a six-volume Final Technical Report as follows:

VOLUME I. User's Manual - Airframes Volume 1
Contains:
- Utilization Procedures
- Trade-Off Study Examples
- MC/DG Sections for:
  - Sheet Metal
  - Mechanically Fastened Assembly
  - Composites

VOLUME II. User's Manual - Airframes Volume 2
Contains:
- MC/DG Sections for:
  - Extrusions
  - Castings
  - Forgings

VOLUME III. User's Manual - Airframes Volume 3
Contains:
- MC/DG Test, Inspection & Evaluation Section for:
  - Sheet Metal
  - Mechanically Fastened Assemblies
  - Castings
  - Forgings
  - Machining
  - Composites

VOLUME IV. User's Manual - Electronics Volume 1
Contains:
- Design Process Descriptions
- Conceptual Design Section for:
  - New Technology
  - Number of Assemblies
  - Common Functions
  - Digital Design
  - Built-in Test
  - Part Count
  - Part Selection
    -- Reliability
    -- Package
- Detail Design Section for:
  - Mechanization
  - Processes
  - Insertion Process
  - Soldering Process

VOLUME V. Project Summary

VOLUME VI. Technology Transfer Summary and Report Contents

FOREWORD

This Manufacturing Cost/Design Guide document covers the work performed under Air Force Contract F33615-79-C-5102 from 1 October 1979 through 1 October 1982. The contract is sponsored by the Computer Integrated Manufacturing Branch, Manufacturing Technology Division, Materials Laboratory, Air Force Wright Aeronautical Laboratories. The ICAM Project Manager is Capt. Richard R. Preston. In previous phases, the following Air Force personnel directed the program; Mr. John R. Williamson, Capt. Dan L. Shunk, and Capt. Steven R. LeClair.

The organization of the program is comprised of a coalition of seven participating companies with Battelle's Columbus Laboratories (BCL) as the prime contractor. Mr. Bryan R. Noton is the BCL Program Manager. The other participating companies of the coalition are listed below:

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Note that the number and date in the upper right corner of each page of this document indicates that the document has been prepared according to ICAM's Configuration Management Life Cycle Documentation requirements for Configuration Items (CIs).

Approved by: Bryan R. Noton
BRYAN R. NOTON,
MC/DG Program Manager

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4.4 Extrusion Section

This section contains format selection aids, identification of the types of parts analyzed for data to determine the manufacturing man-hour data, examples of how the data are utilized in airframe design and a set of formats. These formats include cost-driver effects (CDE), cost-estimating data (CED), and designer-influenced cost elements (DICE).

4.4.1 Format Selection Aids

Format selection aids are presented to provide the user with a building-block approach to determine manufacturing cost data for alternative designs or processes. The designer can review the format selection trees and identify those areas that have an impact on his design. The formats provide cost-driver effects (CDE) for qualitative guidance to lowest cost and cost-estimating data (CED) in man-hours for conducting trade studies.

Selection aids are provided in the MC/DG Section for Extrusions for the following categories of formats:

(a) Cost-driver effect of material extrusion and fabrication cost for curved parts in aluminum, titanium, and steel (CDE-EXTN-I to VI).

(b) Determination of material cost and related factors (CED-EXTN-1 to 7) in aluminum, titanium, and steel.

(c) Cost-estimating data for straight and contoured extrusions in aluminum, titanium, and steel (CED-EXTN-8 to 15), and also, designer-influenced cost elements (DICE-EXTN-1 to 5). DICE considered for extrusions are joggles, flanged holes, heat treatment and trim.

The designer first reviews CDE formats for guidance to the lowest cost. The selection aids indicate the scope of these formats. The designer then utilizes the CED formats.

A Cost Worksheet for Extrusions is included for use at the discretion of the designer to determine costs of the discrete part cost and/or the total program cost.

FORMAT SELECTION AID

EXTRUDED AEROSPACE DISCRETE PARTS COST-DRIVER EFFECTS

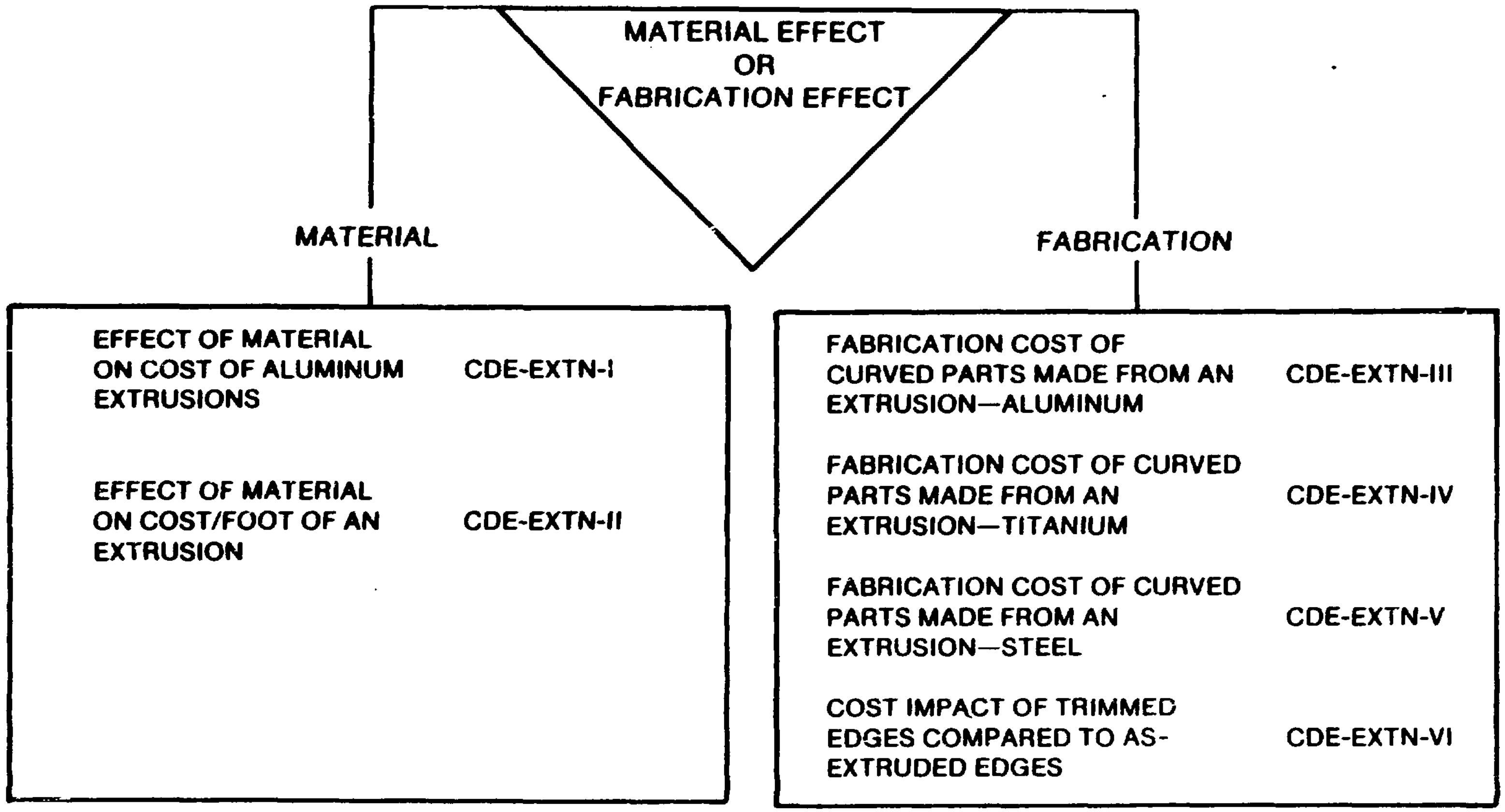
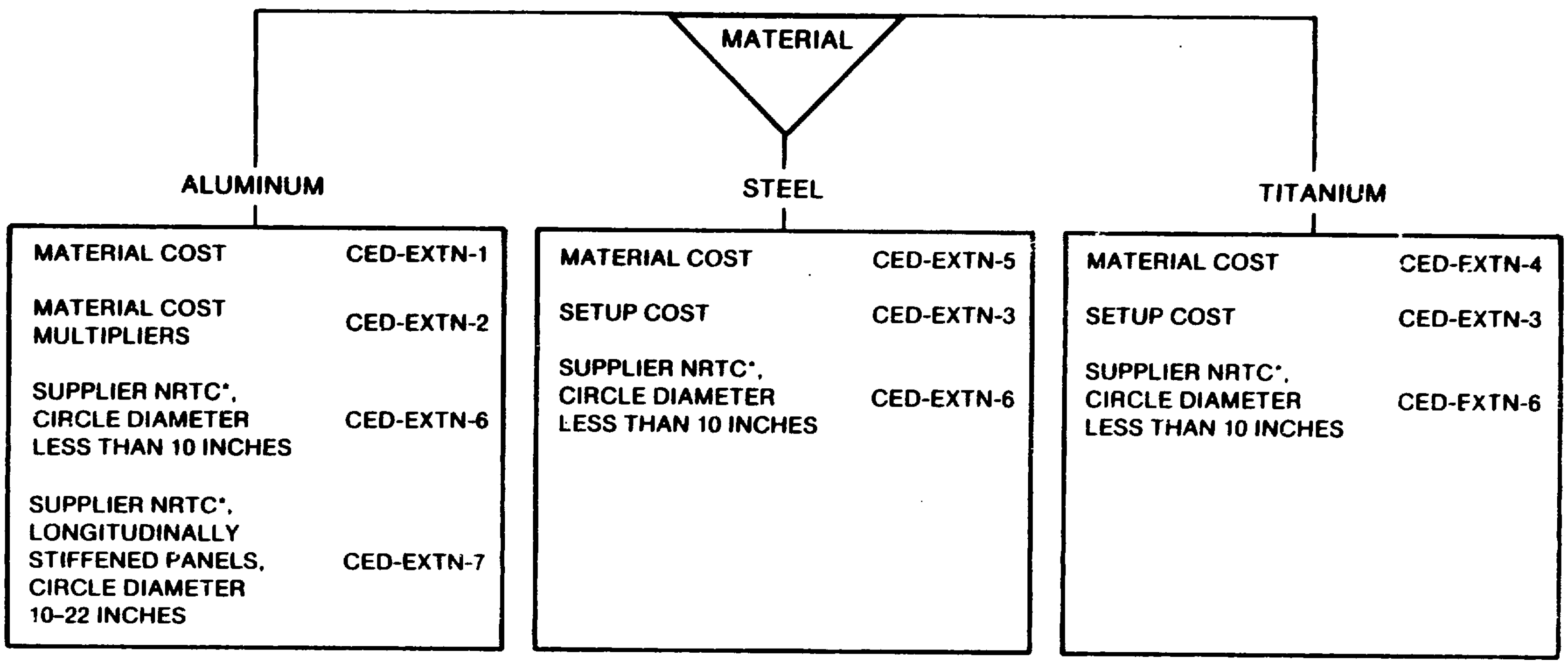


FIGURE 4.4-1

FORMAT SELECTION AID

EXTRUDED AEROSPACE DISCRETE PARTS
MATERIAL COST

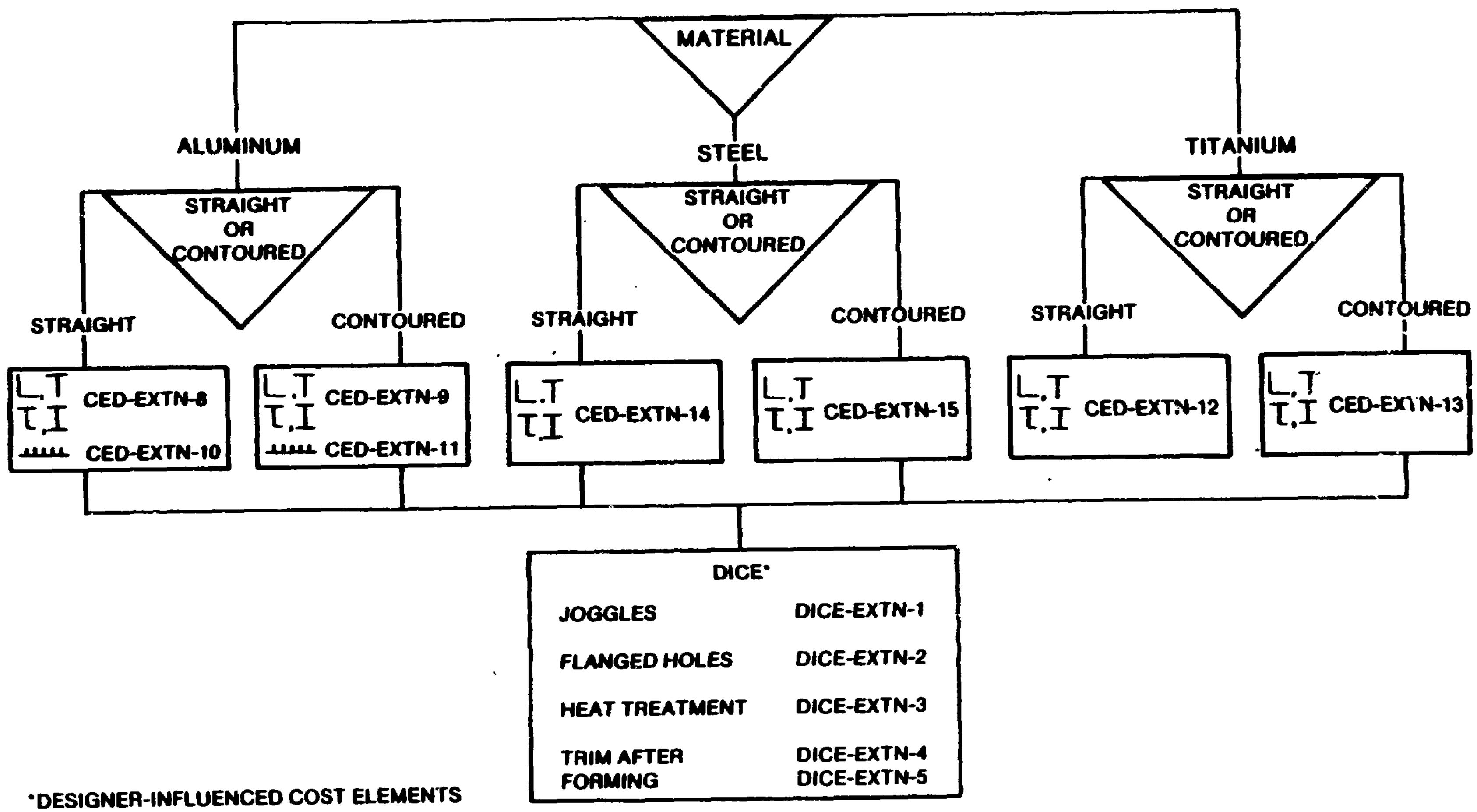


*NONRECURRING TOOL COST

FIGURE 4.4-2

FORMAT SELECTION AID

EXTRUDED AEROSPACE DISCRETE PARTS COST-ESTIMATING DATA (CED)



*DESIGNER-INFLUENCED COST ELEMENTS

FIGURE 4.4-3

4.4.2 Example of Utilization

This example demonstrates how the data generated are utilized on a specific design problem. The example shows how to identify applicable formats, how to extract data from the formats, and provides a discussion on how the data are used to determine the part cost in man-hours or dollars. The MC/DG cost worksheet can be used to record the cost data for easy reference and to determine the total program cost. The worksheet is included as Table 4.4-1.

4.4.2.1 Material Cost for Aluminum Extrusions

Problem Statement

To determine the material cost for an aluminum extrusion:

1. Calculate the extrusion factor per example (page 4.4-7).
2. Using the extrusion factor from CED-EXTN-1 (Figure 4.4-5), determine the base price in 1983 dollars/pound.

   NOTE: Use the 7075-T6511 curve for all extrusions except 6061 and wide ribbed shapes.
3. Select multiplier from Table CED-EXTN-2 (Figure 4.4-6).
4. Multiply the airplane design quantity by the number of parts per airplane (include both LH & RH) to arrive at the total number of parts. From CED-EXTN-3 (Figure 4.4-7), determine the extrusion supplier setup cost in 1982 dollars/part.
5. Calculate recurring material cost/part:

   Material Cost/Part = [part length (ft) x extrusion weight (lb/ft) x base price ($/lb) x multiplier + setup cost] x inflation factor.
6. Determine the nonrecurring cost from CED-EXTN-6 (Figure 4.4-10) or CED-EXTN-7 (Figure 4.4-11).

4.4.2.2 Material Cost for Titanium/Steel Extrusions

Problem Statement

Note that then calculating extrusion cross-sectional area and weight, all surfaces of titanium and steel extrusions must be machined. A machining allowance of 0.06 and 0.012 in. per surface should be made.

To determine the material cost of a titanium or steel part:

1. Calculate the extrusion weight (pounds/foot).
2. From CED-EXTN-4 (Figure 4.4-8) or CED-EXTN-5 (Figure 4.4-9), determine the price in dollars/pound for the appropriate material.

3. Calculate recurring material cost:

   Material cost/part = [part length (ft) x weight (lb/ft) x cost ($/lb) + setup cost] x inflation factor.

4. Determine nonrecurring cost from CED-EXTN-6 (Figure 4.4-10).

4.4.2.3 Cost of Aluminum Extrusion

Problem Statement

Determine the cost of a Tee Section of dimensions 4" x 1.5" x 0.250".

- Weight: 1.28 lb/ft
- Extrusion Factor: 7

Part Length: 10 ft

Material: 7075-T76511

Parts/Airplane: 2

Design Quantity: 200

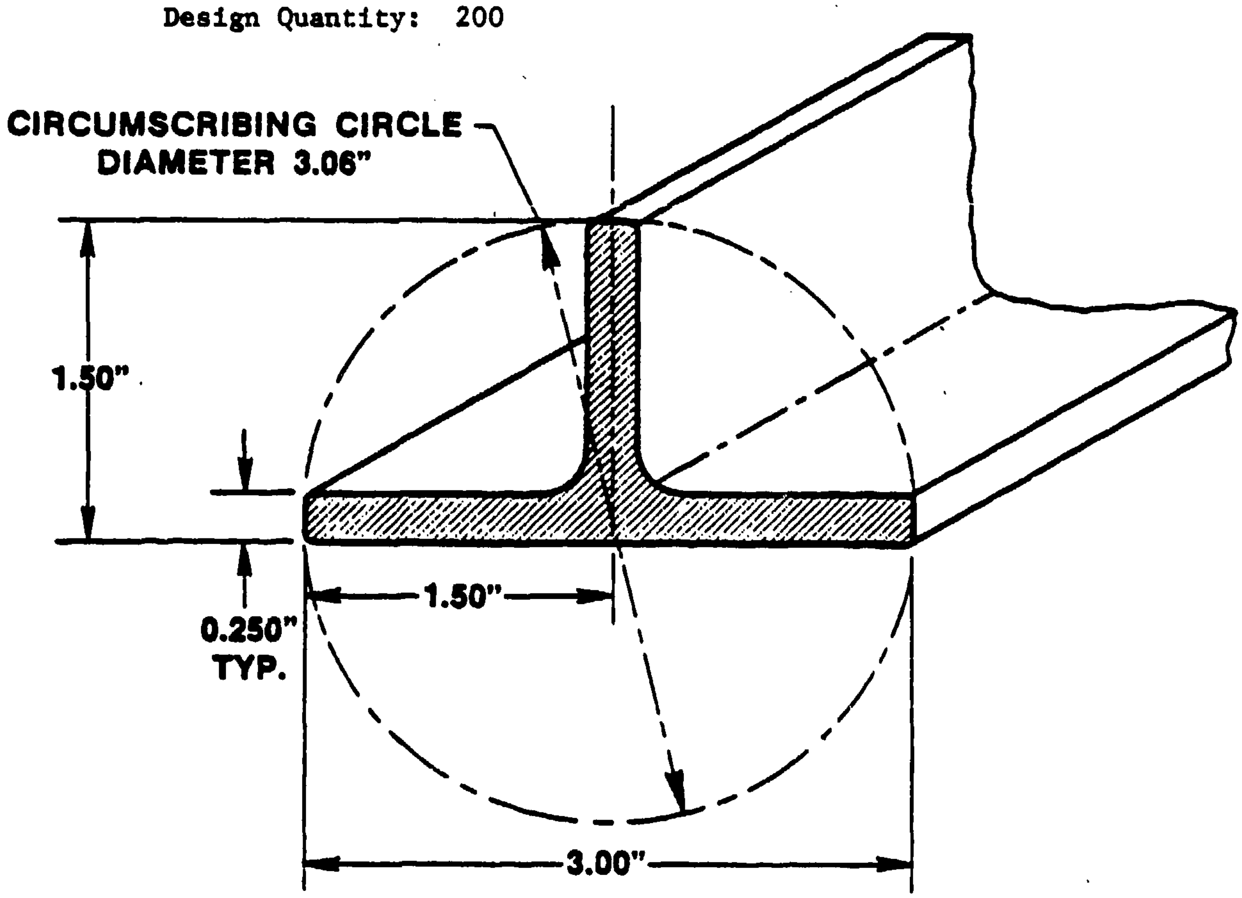


FIGURE 4.4-4. EXTRUSION ANALYZED

The extrusion factor must first be determined:

(a) Calculate cross-sectional area perimeter (inches)

Perimeter = (2 x 3.00 + 2 x 1.50) in

= 9 in.

(b) Calculate extrusion weight (pounds/foot)

Cross-sectional area = 0.250 (3.00 + 1.50-0.25) $in.^2$

= 1.0625 $in.^2$

Weight = area x 12"/ft x density

= 1.0625 x 12 x 0.1

= 1.275 lb/ft

(c) Calculate factor

$$\text{Factor} = \frac{\text{perimeter (inches)}}{\text{weight (pounds/foot)}}$$

$$= \frac{\text{9 inches}}{\text{1.275 lb/ft}}$$

= 7.06

(d) This factor is used to determine the aluminum extrusion price.

1. From CED-EXTN-1: Base price is $4.10/lb
2. From CED-EXTN-2: Multiplier is 1.10
3. From CED-EXTN-3: Setup cost is $2.50/part
4. Inflation factor 1982: 1
5. Use recurring material cost/part formula:
   - Material cost/part = [10 ft x 1.28 lb/ft x $4.10/lb
     4.10/lb x 1.1 + $2.50]1
     = $60.23
6. Circumscribing circle size is 3+ inches.
   - From CED-EXTN-6, Nonrecurring Tool Cost (NRTC) is $325.

4.4.2.4 Cost of Titanium Extrusion

Problem Statement

Determine the cost of a titanium "T" section of dimensions 3" x 1.5" x 0.250" (cross-sectional area = 1.0625 $in.^2$)

Part length: 10 ft

Material: 6 Al-4V

Parts/airplane: 2

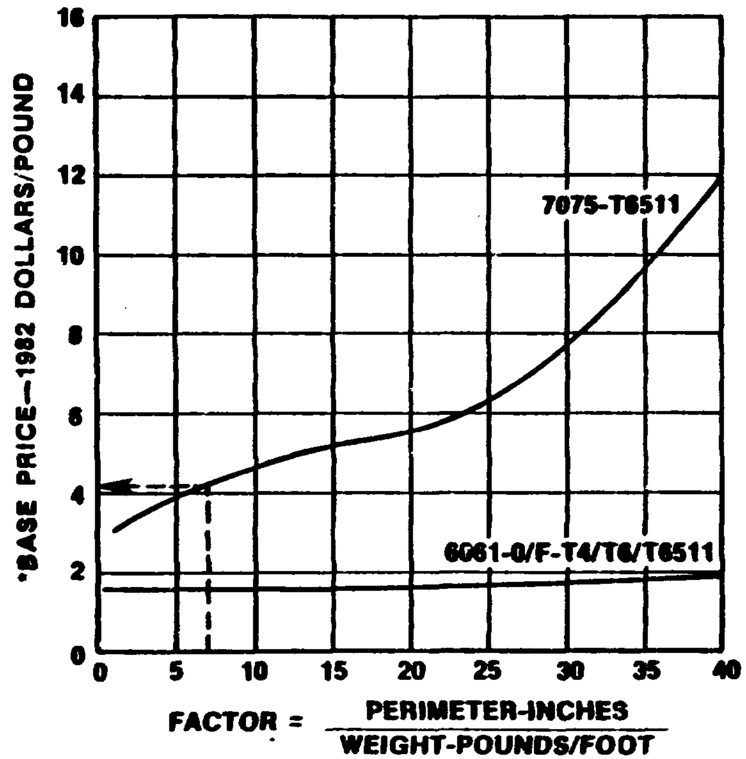
Design quantity: 100

1. Weight/ft = 1.0625 x 12 x 0.160
   = 2.04 lb/ft
2. From CED-EXTN-4: Base price is $31.85/lb
3. From CED-EXTN-3: Setup cost is $5.00/part
4. Inflation factor 1982: 1
5. Recurring material cost/part
   = (10 ft x 2.04 lb/ft x $31.85/lb + $5.00) x 1
6. From CED-EXTN-6, Nonrecurring Tool Cost (NRTC) is $865.

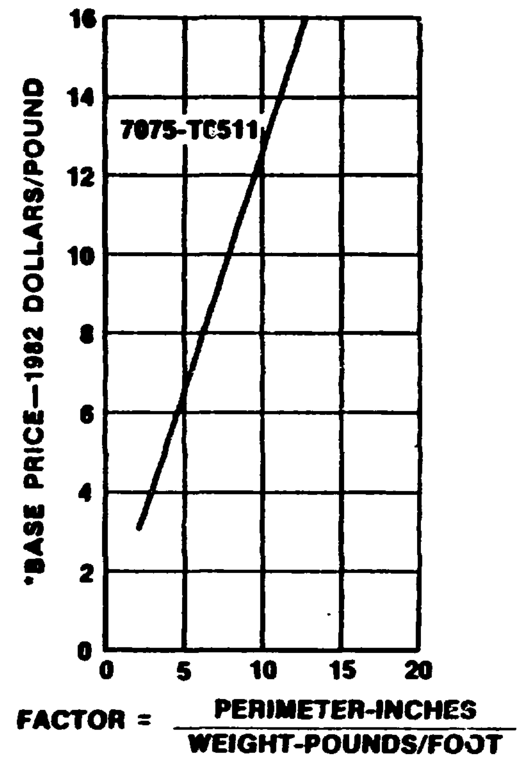
MATERIAL COST—ALUMINUM

SOLID SHAPES

CIRCUMSCRIBING CIRCLE DIAMETER UP TO 10"



LONGITUDINALLY STIFFENED PANELS/SLABS CIRCUMSCRIBING CIRCLE DIAMETER 10"-24"



CED-EXTN-1

*INCLUDES TESTS, INSPECTION AND EVALUATION (TI&E) COST FOR THE AS-EXTRUDED MATERIAL.

FIGURE 4.4-5. FORMAT USED IN EXAMPLE

MATERIAL COST—ALUMINUM

ALUMINUM ALLOY	ALUMINUM TEMPER	MULTIPLIER
7075	T6	1.00
	T6511	1.00
	T73511	1.10
	T76511	1.10
	F	0.87
	O	0.89
7178	T6	1.20
	T6511	1.20
	T73511	1.32
	T76511	1.32
	F	1.04
	O	1.07
2024	T4	0.80
	T3511	0.80
	F	0.70
	O	0.71
2014	T6	0.67
	T6511	0.67
	F	0.58
	O	0.60
6061	All	1.00

CED-EXTN-2

FIGURE 4.4-6. FORMAT USED IN EXAMPLE

MATERIAL—EXTRUSION SETUP COST FOR ALUMINUM, TITANIUM & STEEL

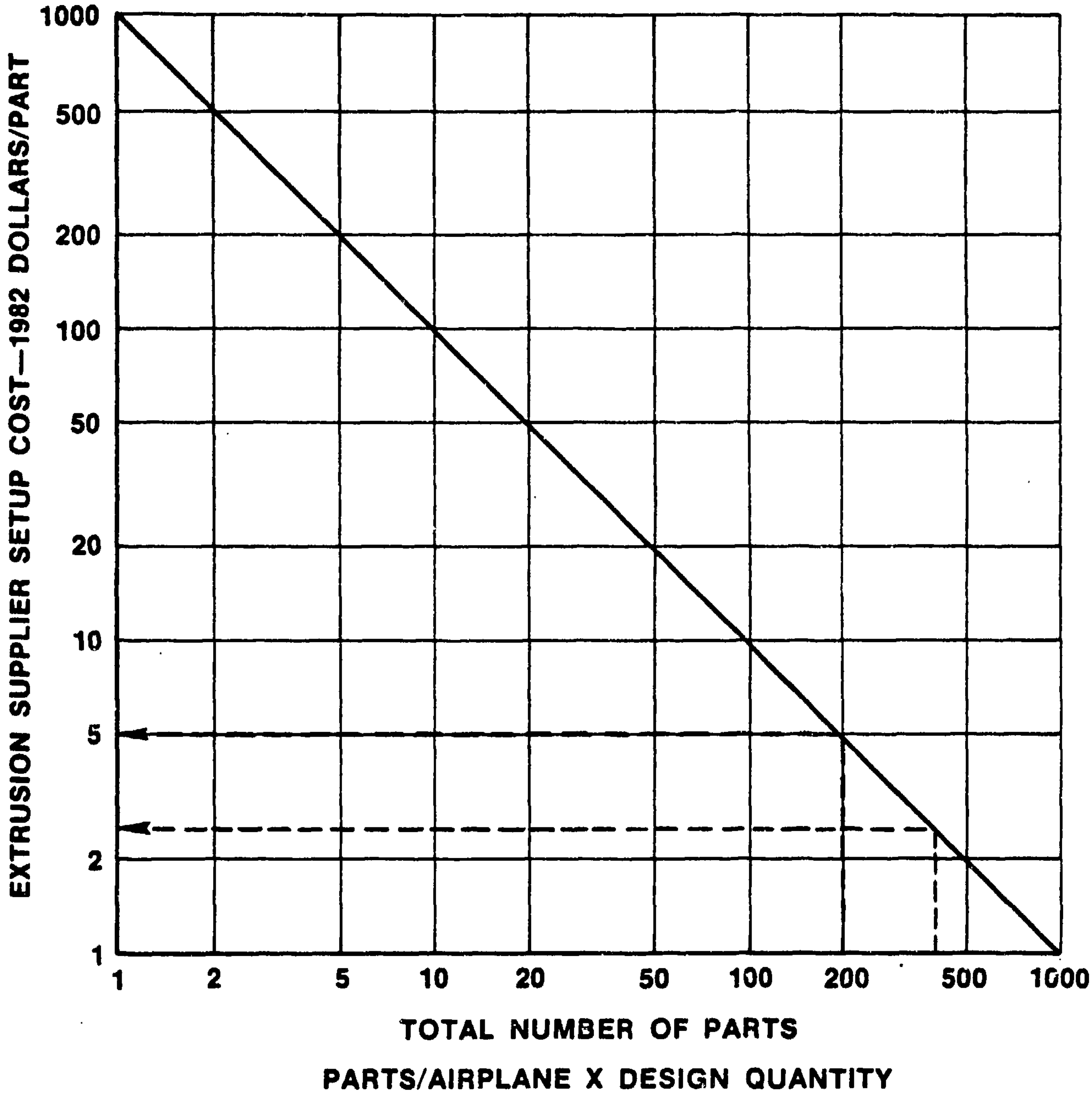
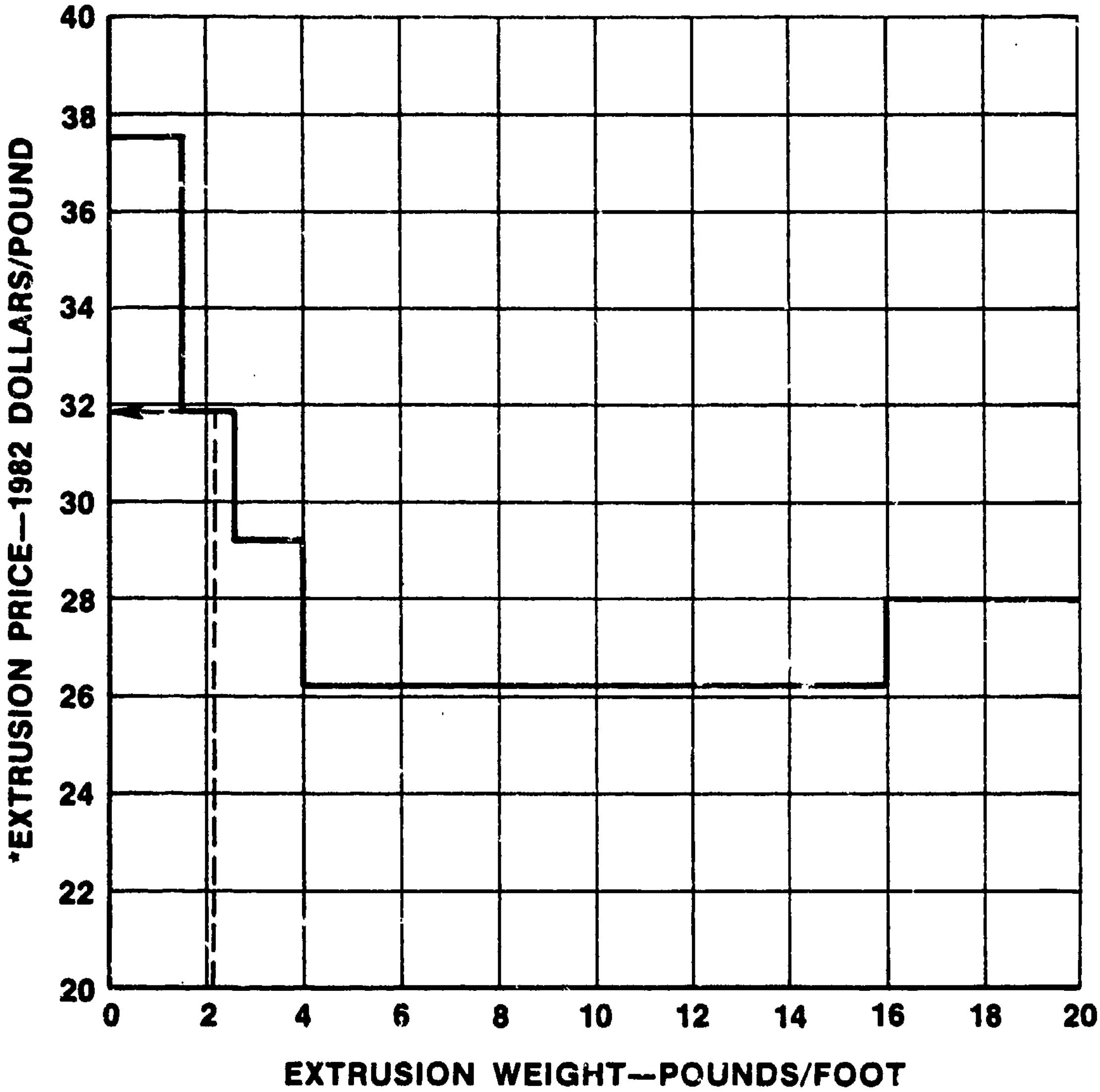


FIGURE 4.4-7. FORMAT USED IN EXAMPLE

CED-EXTN-3

MATERIAL COST—TITANIUM
Ti 6AL-4V



***INCLUDES TEST, INSPECTION, AND EVALUATION (TI&E) COST FOR THE AS-EXTRUDED MATERIAL.**

CED-EXTN-4

FIGURE 4.4-8. FORMAT USED IN EXAMPLE

MATERIAL COSTS - STEEL

Based upon limited historical cost data in the absence of published price schedules, approximate material costs for steel extrusions are:

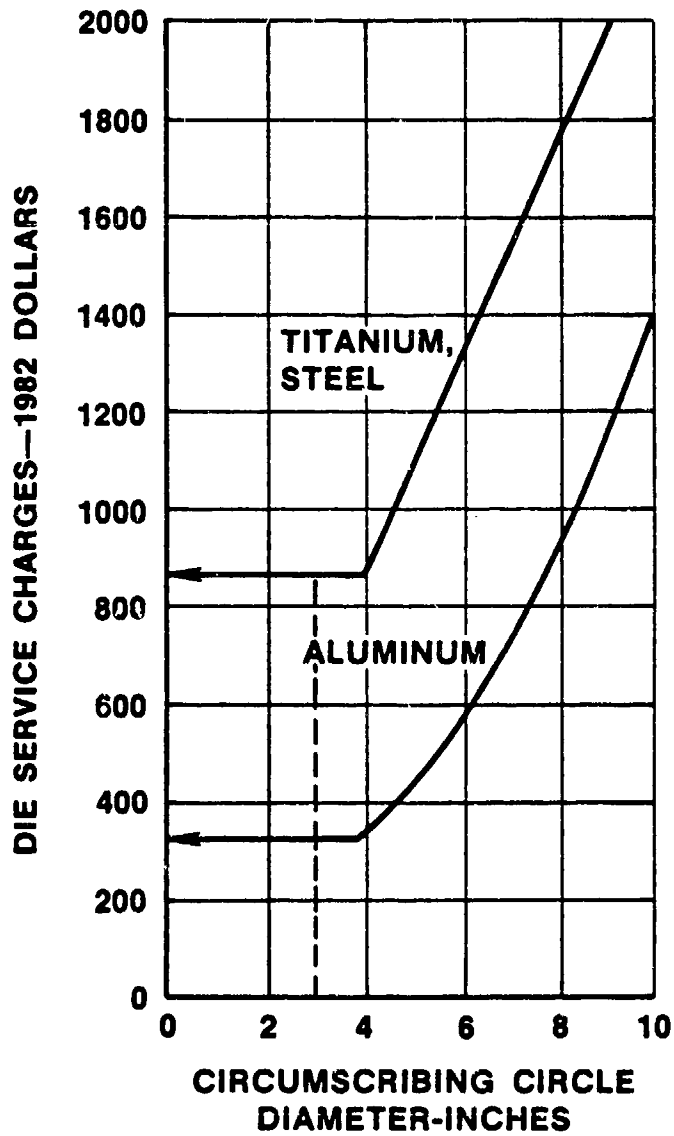
	1982 Cost*
Low Alloy Steels 4130, 4140, 4340, 8630	$3.50/Lb
PH13-8Mo CRES	$16.50/Lb

* Includes TI&E cost for the as-extruded material.

CED-EXTN-5

FIGURE 4.4-9. FORMAT USED IN EXAMPLE

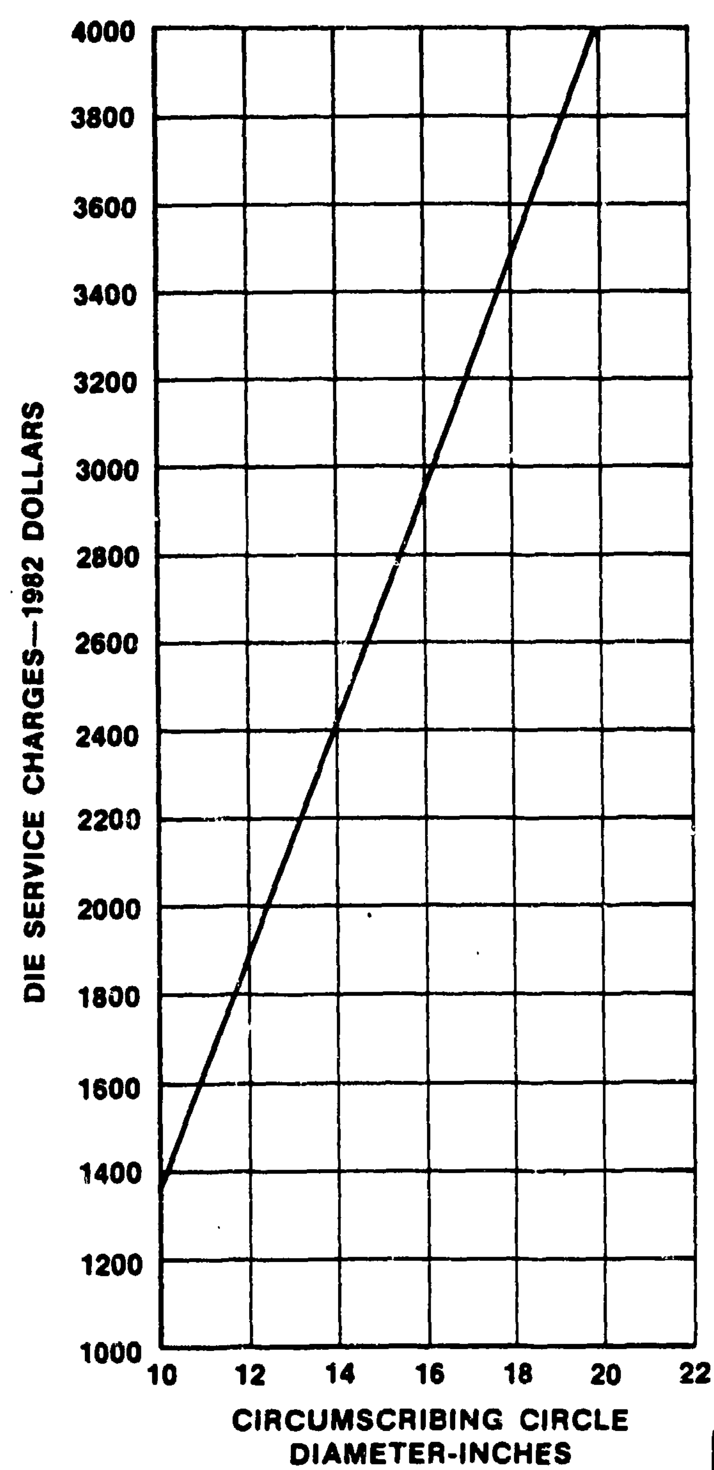
SUPPLIER NONRECURRING TOOL COST CIRCUMSCRIBING CIRCLE UNDER 10" DIAMETER



CED-EXTN-6

FIGURE 4.4-10. FORMAT USED IN EXAMPLE

SUPPLIER NONRECURRING TOOL COST FOR LONGITUDINALLY STIFFENED PANELS/SLABS CIRCUMSCRIBING CIRCLE DIAMETER 10"-22"



CED-EXTN-7

FIGURE 4.4-11. FORMAT USED IN EXAMPLE

TABLE 4.4-1.
EXTRUSIONS-COST WORKSHEET

PART NO.: **DESCRIPTION:** **DESIGNER:** **DATE:**

MATERIAL COST*

_____ Sq In. (Cross Section Area) x _____ Lb/In.^{3} (Density) = _____ Lb/Ft (Weight)

Base Price (CED-EXTN- _____) $_____ /Lb

ALUMINUM ONLY:

_____ In./ (Perimeter) _____ Lb/Ft (Weight) = _____ (Factor)

Alloy/Temper Multiplier (CED-EXTN-2) _____

_____ (Des. Qty.) x _____ (Parts/Airplane) = _____ (Total Qty.) ; Setup Cost (CED-EXTN-3) = $_____ /Part

Mat'l/Part = _____ Ft (Length†) x _____ Lb/Ft (Weight) x $_____ /Lb (Base Price) x _____ (*Multiplier) + $_____ Ea. (Setup) _____ (**Inflation) $_____ (a)

Nonrecurring Extrusion Die Cost (CED-EXTN- _____) $_____ (b)

*Aluminum Only **Inflation Factor to be Supplied by User Company

FABRICATION COST	FORMAT NUMBER	RECURRING COST	NONRECURRING COST
BASE PART COST _____	CED-EXTN-	MH	MH
DICE - _____	DICE-EXTN-	MH	MH
DICE - _____	DICE-EXTN-	MH	MH
Test, Inspection & Evaluation _____	CED-	MH	MH
TOTAL FABRICATION COST (UNIT 200)		(c) MH	(d) MH
(e) Learning Curve Factor—See Table Below			
(f) Labor Rate		$ /MH	$ MH
(g) Fabrication Cost—Recurring/Part(c x e x f)		$ EA	
(h) Fabrication Cost—Nonrecurring(d x f)			$

COST SUMMARY	
(a) Material Cost/Part	$
(g) Fabrication Recurring Cost/Part	$
(i) Design Quantity	
(j) Program Recurring Cost (a + g) i	$
(b) Nonrecurring Cost—Material	$
(h) Nonrecurring Cost—Fabrication	$
(k) Nonrecurring Cost—Total (b + h)	$
(m) Program Cost (j + k)	$
(n) Cost/Part (m ÷ i)	$

†Length of extrusion required for curved (stretch formed) parts is part length + 2 feet.

Des. Qty	LC Factor	Des. Qty	LC Factor
1	2.25	200	1.17
10	1.79	300	1.06
25	1.50	500	1.02
50	1.44	750	0.96
100	1.30	1000	0.92

90% Learning Curve Factor to Convert Unit 200 Format cost to Cumulative Average cost for Various Design Quantities.

4.4.3 Parts Analyzed

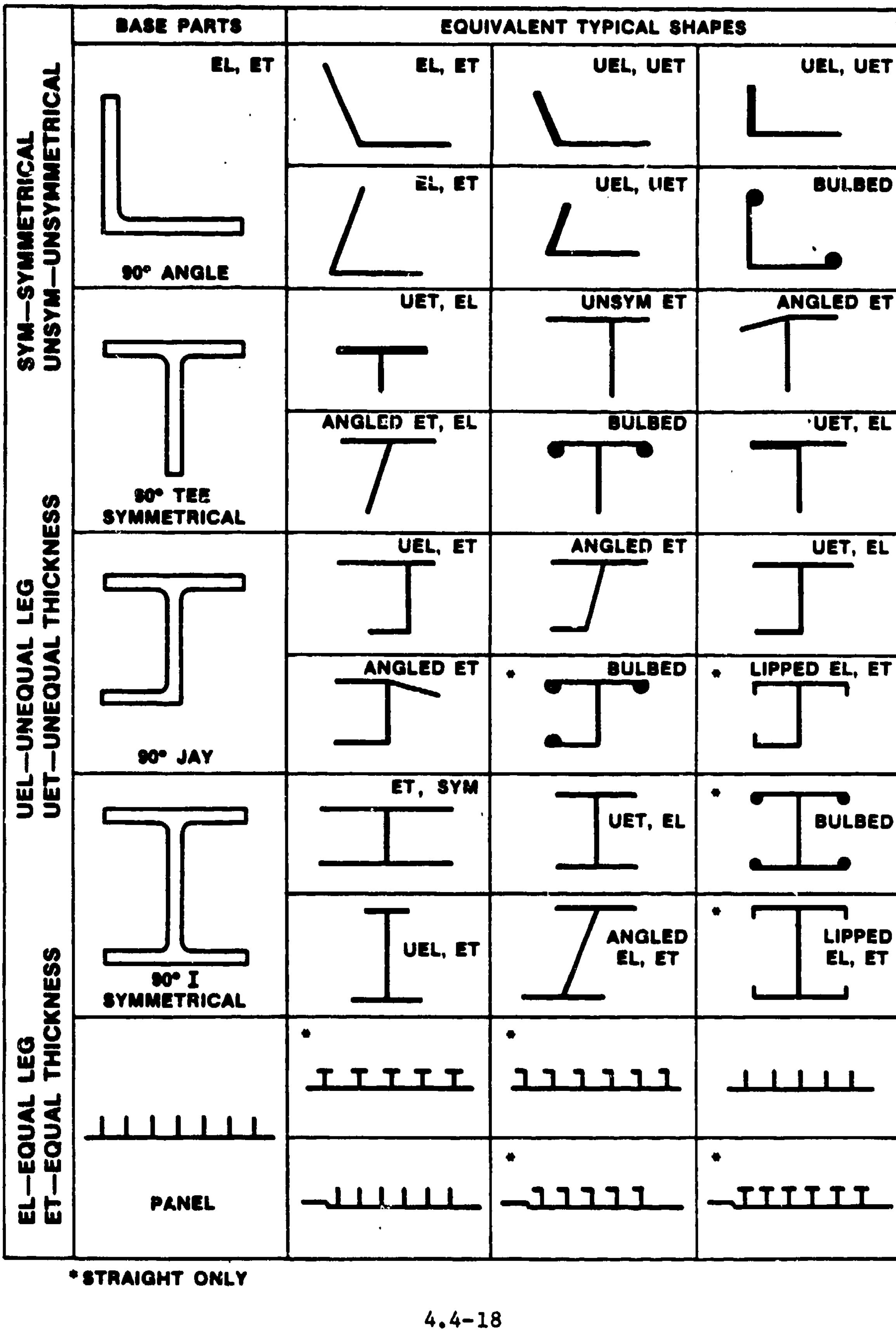
The data for the extruded base parts and designer-influenced cost elements (DICE) evaluated are applicable to the extruded shapes in Figure 4.4-12. As indicated in the ground rules in this section, manufacturing man-hour information is also provided for 6Al-4V titanium and also PH13-8 and 4340 steel extrusions. The manufacturing operations for aluminum, titanium, and steel extrusions are shown in Figures 4.4-13 to 4.4-15.

FIGURE 4.4-12.

MC/DG EXTRUSIONS—ALUMINUM

FTR450261000U
3 Jan 1983

CED FORMATS FOR FABRICATION OF BASE PART SH INCLUDING DICE ARE VALID FOR THE EQUIVALENT TYPICAL SHAPES



*STRAIGHT ONLY

FIGURE 4.4-13.

EXTRUSION MANUFACTURING FLOW FOR ALUMINUM

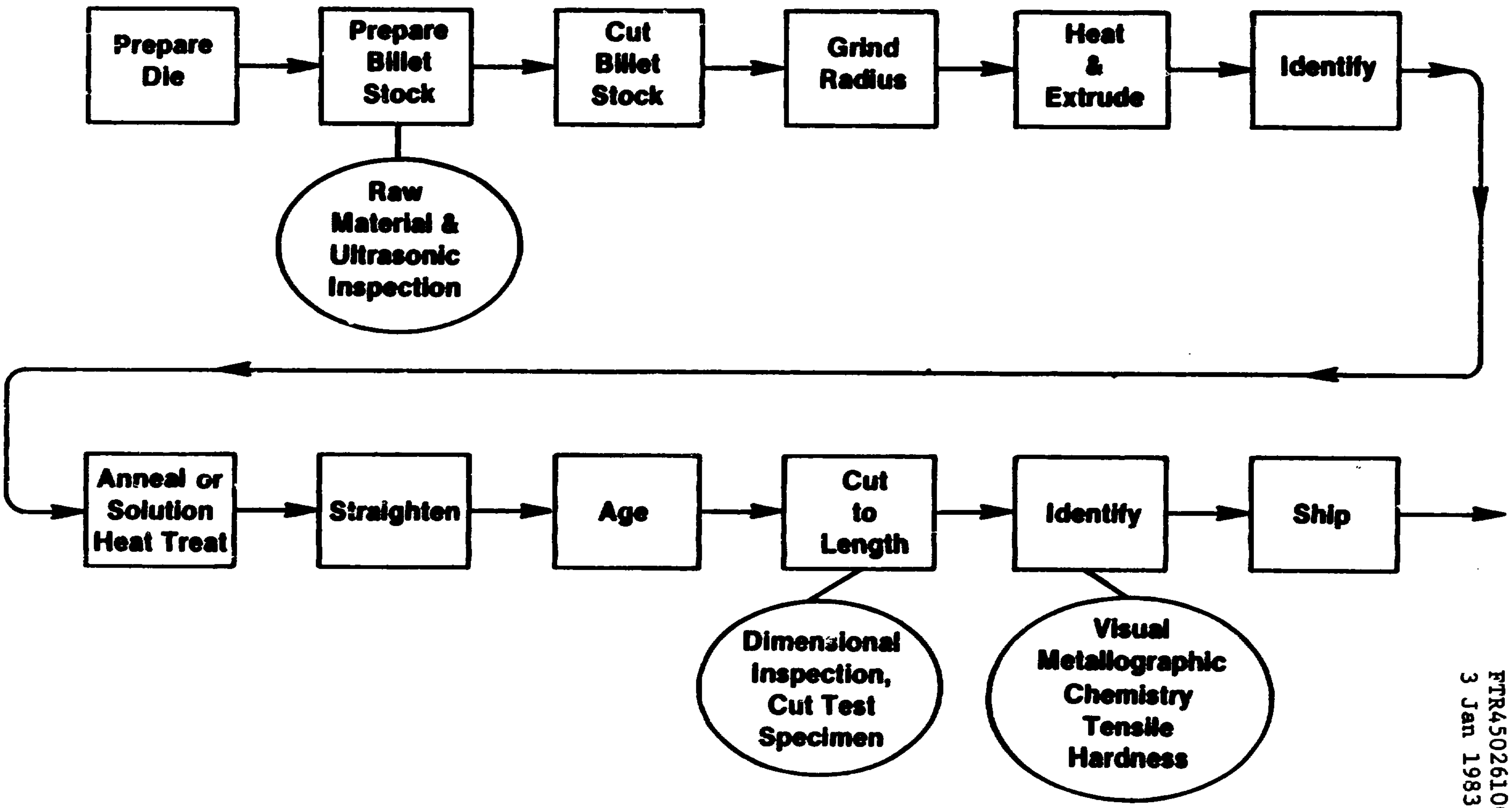


FIGURE 4.4-14

EXTRUSION MANUFACTURING FLOW FOR TITANIUM AND STEEL

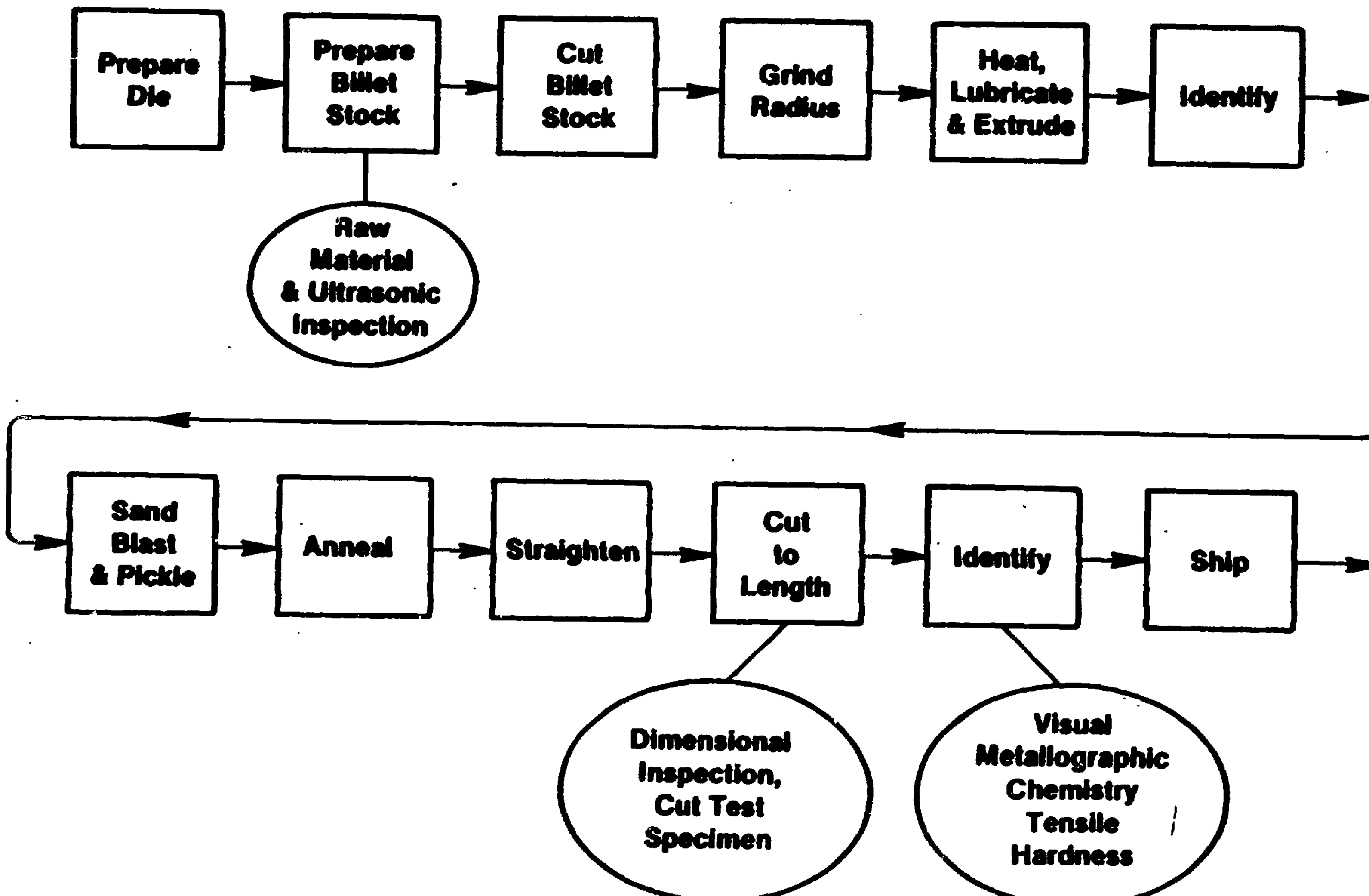
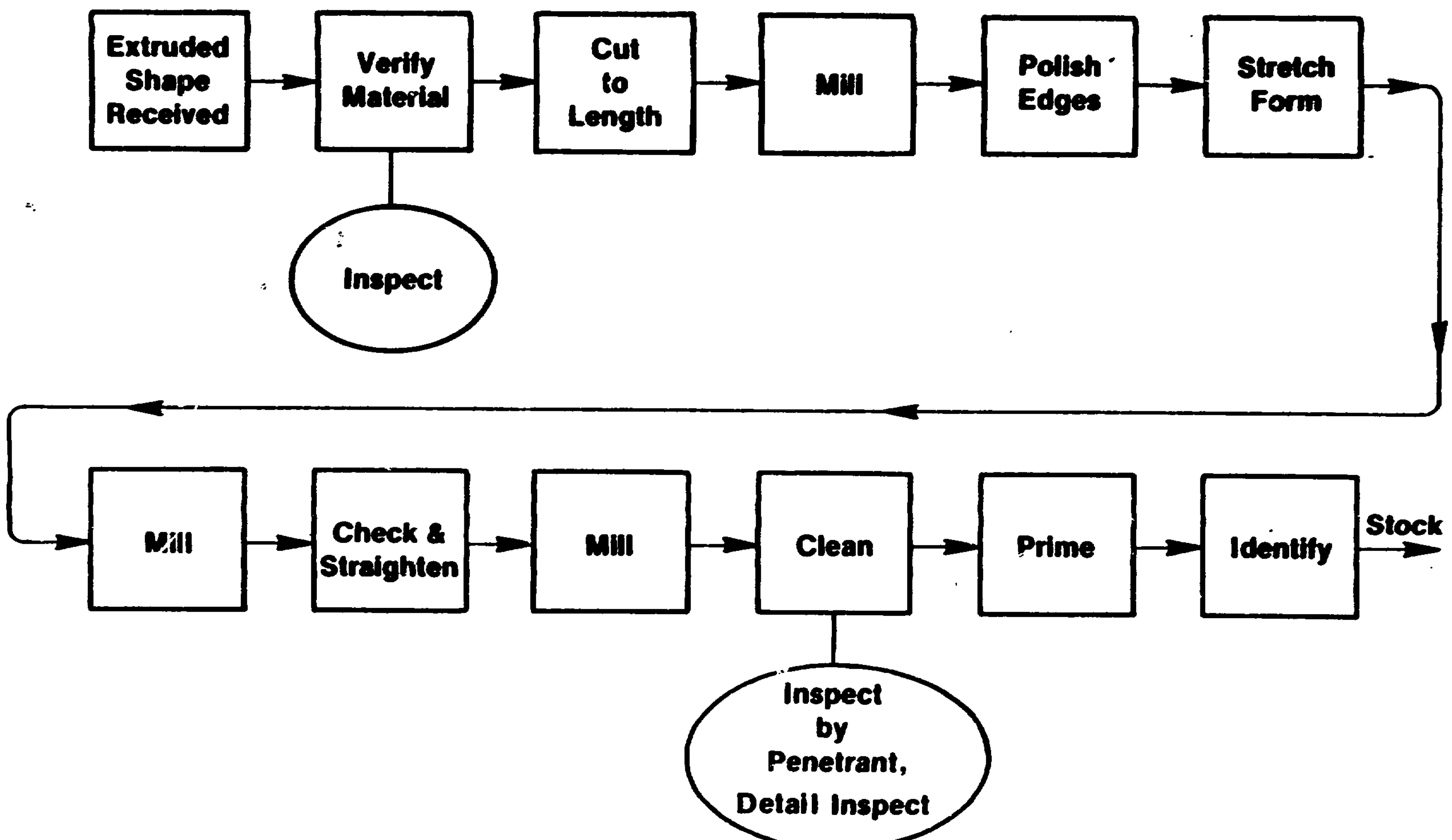


FIGURE 4.4-15.

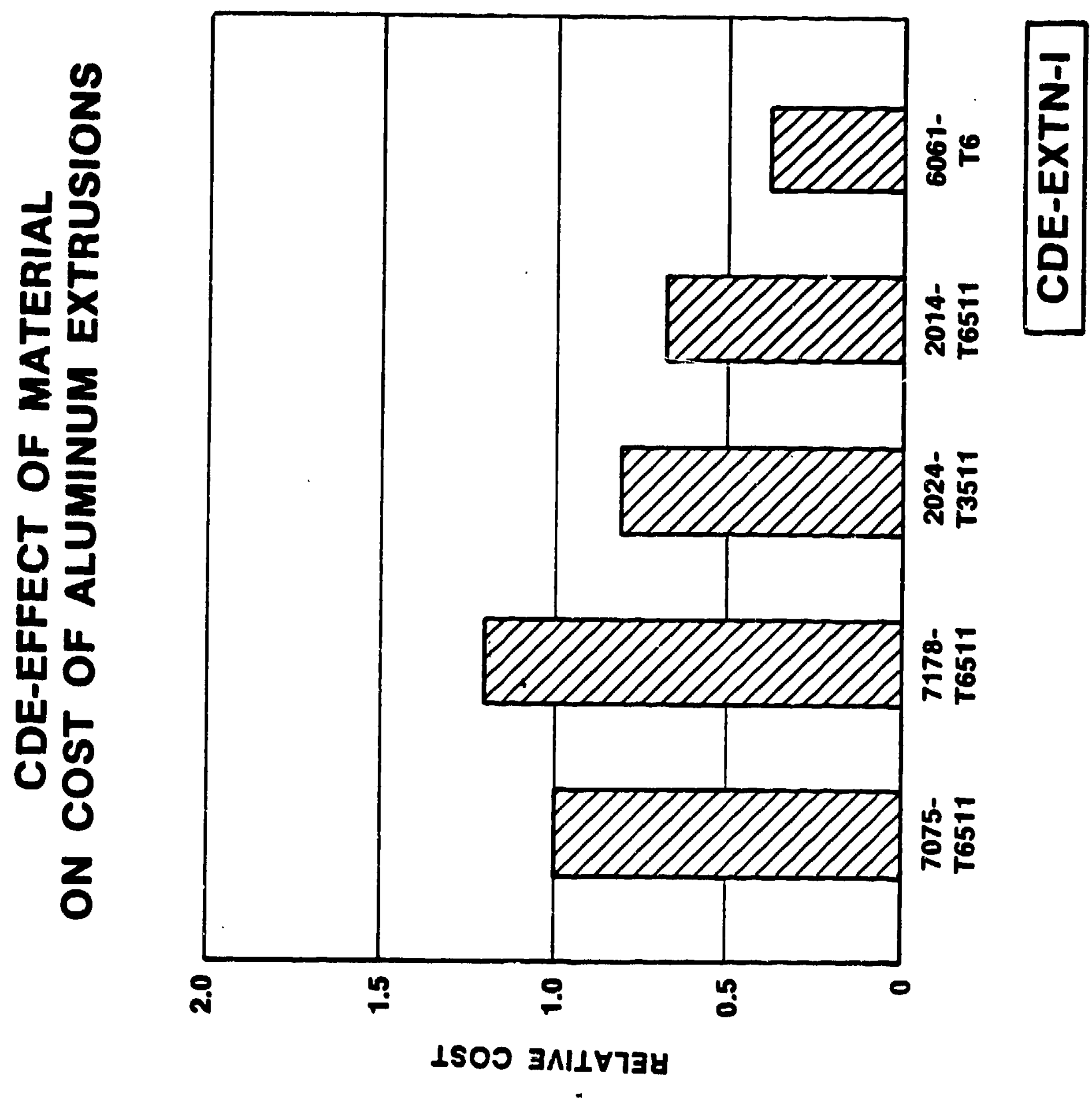
EXTRUSION MANUFACTURING FLOW FOR TITANIUM AND STEEL CURVED SHAPES ONLY



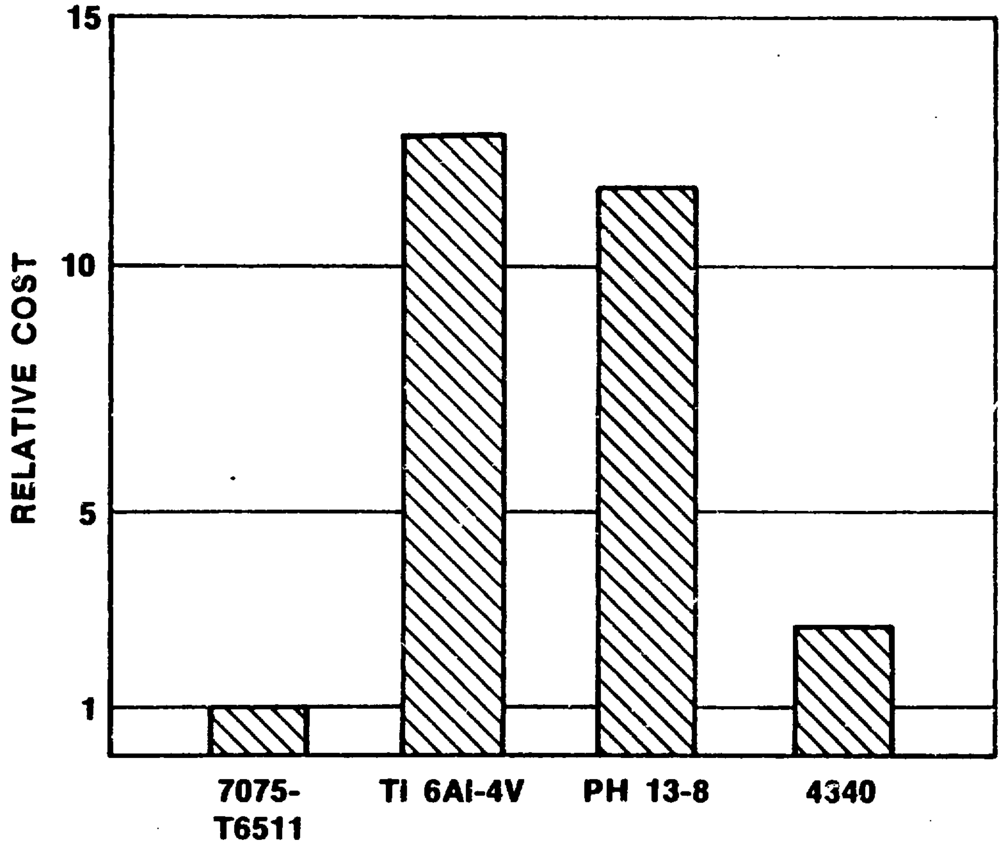
Note: Forming Radius for Stretch-Formed Extrusion Shall be any Contour Compatible with the Material and with the Individual Equipment Limitations.

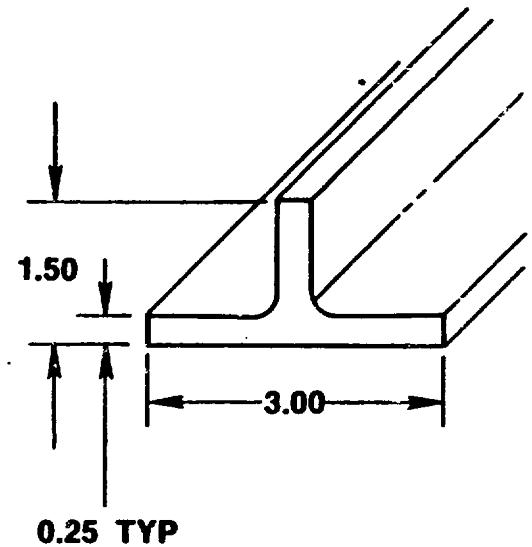
4.4.4 Extrusion Manufacturing Cost Data

The formats on the following pages provide designer guidance in extrusion selection and design and also enable cost trade studies to be conducted. The scope of the formats for extrusions is indicated in Section 4.4.2.


CDE-EFFECT OF MATERIAL
ON COST OF ALUMINUM EXTRUSIONS
RELATIVE COST
2.0
1.5
1.0
0.5
0
7075-T6511
7178-T6511
2024-T3511
2014-T6511
6061-T6
CDE-EXTN-I

CDE-EFFECT OF MATERIAL ON THE COST/FOOT OF AN EXTRUSION



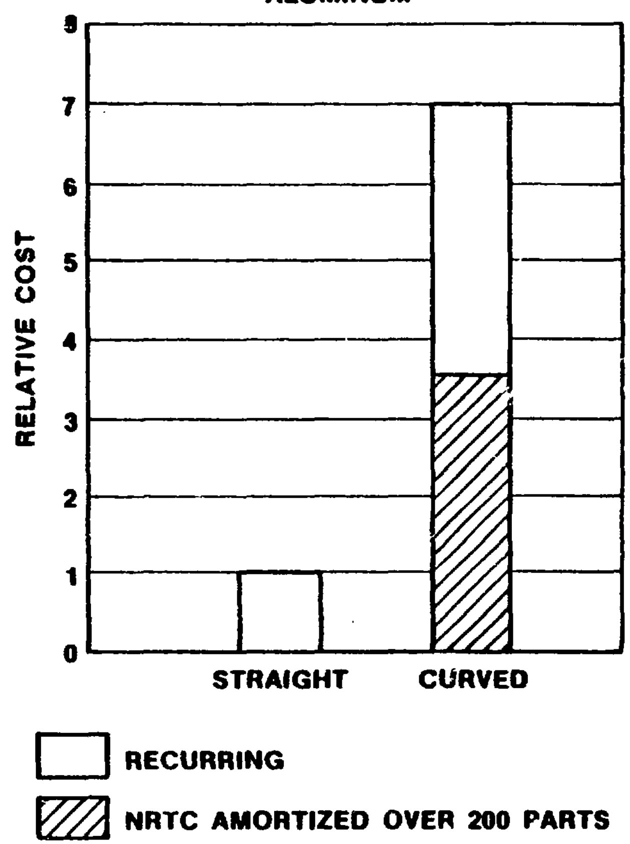


CDE-EXTN-II

CDE-FABRICATION COST OF CURVED PARTS MADE FROM EXTRUSIONS

COMPARISON BASED ON A 8' LONG TEE EXTRUSION

ALUMINUM



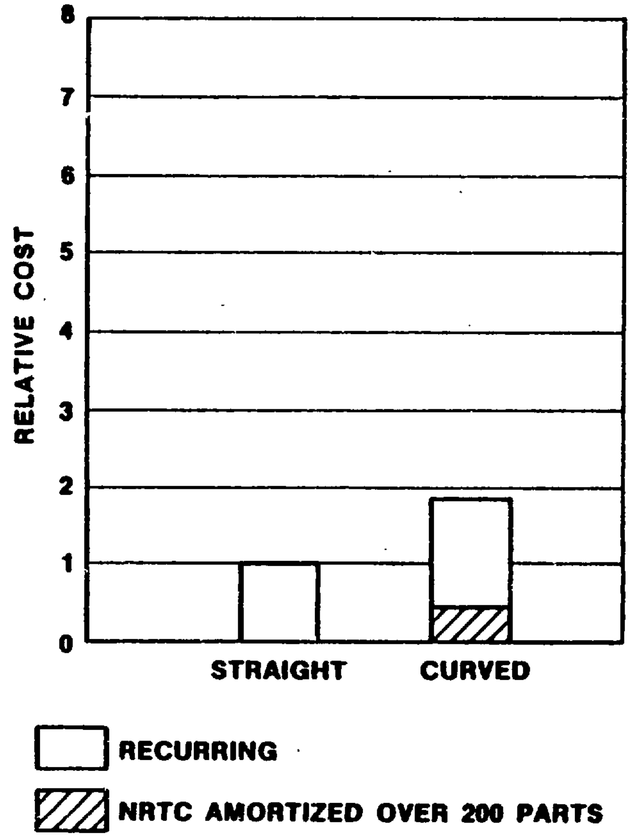
FOR BASELINE REFERENCE, SEE CED NO.

CDE-EXTN-III

CDE-FABRICATION COST OF CURVED PARTS MADE FROM EXTRUSIONS

COMPARISON BASED ON A 8' LONG TEE EXTRUSION

TITANIUM



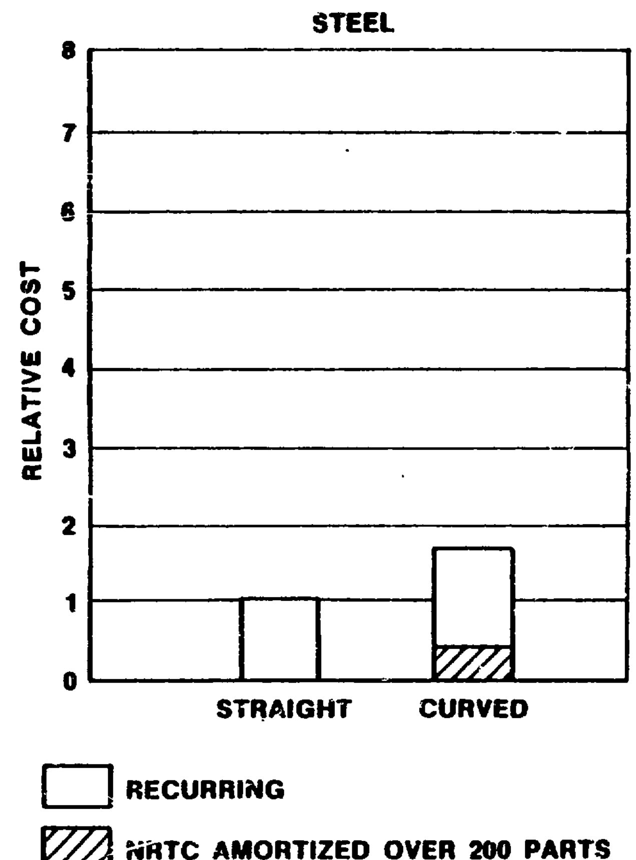
FOR BASELINE REFERENCE, SEE CED NO.

CDE-EXTN-IV

CDE-EXTN-V

CDE-FABRICATION COST OF CURVED PARTS MADE FROM EXTRUSIONS

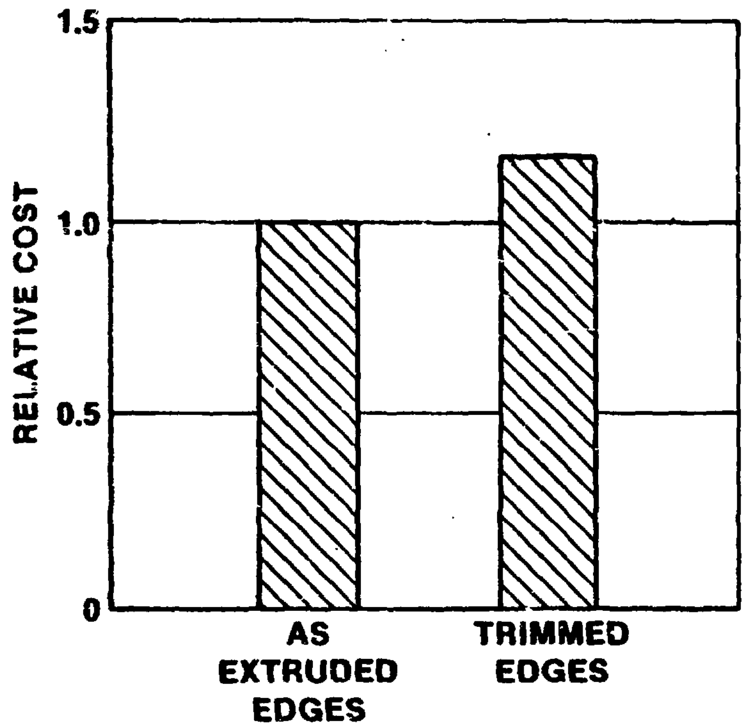
COMPARISON BASED ON A 8' LONG TEE EXTRUSION



FOR BASELINE REFERENCE, SEE CED NO.

CDE-COST IMPACT OF TRIMMED EDGES COMPARED TO AS EXTRUDED EDGES

COSTS INCLUDE MATERIAL, FABRICATION LABOR & NRTC BASED ON 7075-T6 ALUMINUM TEE 3" x 3" x 1/8" THICK 8' LONG FORMED TO A 60" RADIUS.

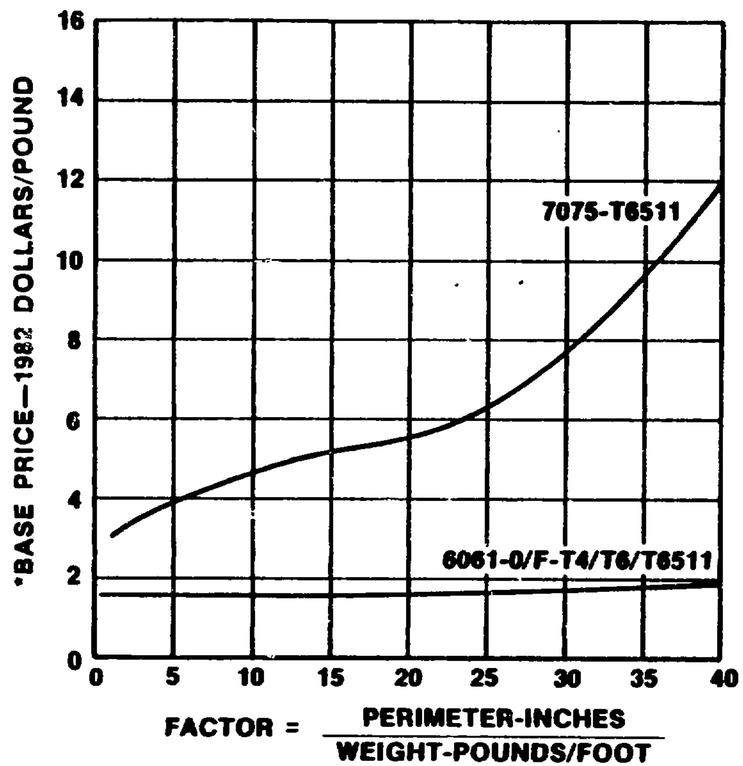


CDE-EXTN-VI

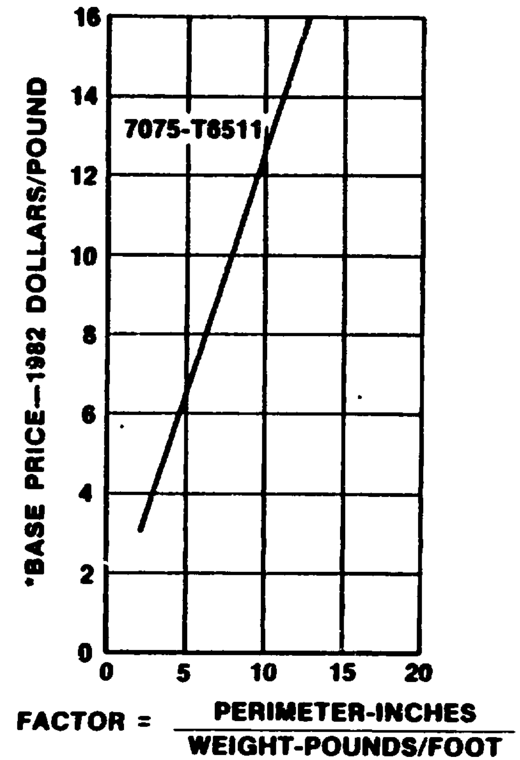
MATERIAL COST—ALUMINUM

SOLID SHAPES

CIRCUMSCRIBING CIRCLE DIAMETER UP TO 10"



LONGITUDINALLY
STIFFENED
PANELS/SLABS
CIRCUMSCRIBING CIRCLE
DIAMETER 10"-24"



*INCLUDES TESTS, INSPECTION AND EVALUATION (TI&E) COST FOR THE AS-EXTRUDED MATERIAL.

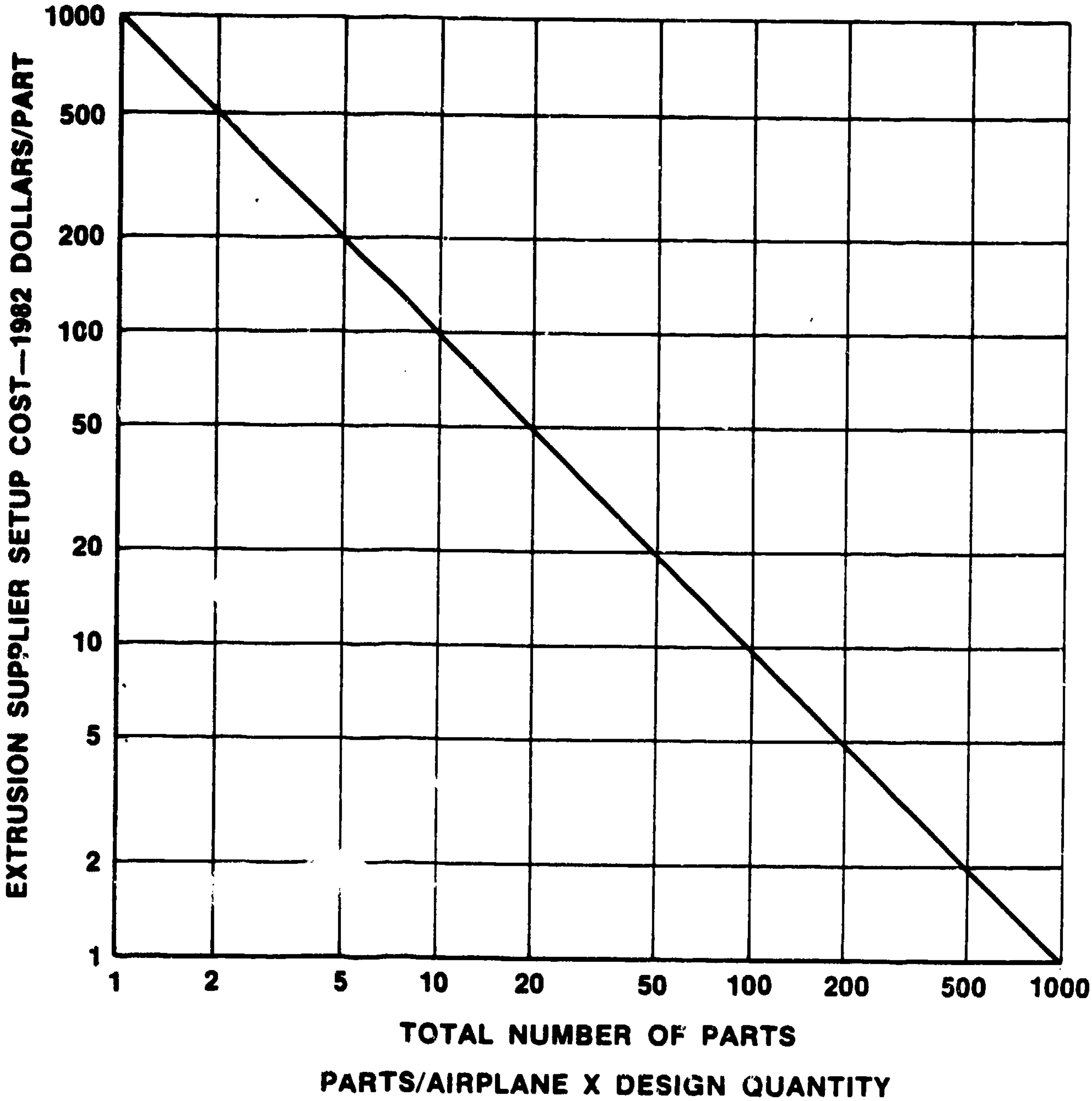
CED-EXTN-1

MATERIAL COST—ALUMINUM

ALUMINUM ALLOY	ALUMINUM TEMPER	MULTIPLIER
7075	T6	1.00
	T6511	1.00
	T73511	1.10
	T76511	1.10
	F	0.87
	O	0.89
7178	T6	1.20
	T6511	1.20
	T73511	1.32
	T76511	1.32
	F	1.04
	O	1.07
2024	T4	0.80
	T3511	0.80
	F	0.70
	O	0.71
2014	T6	0.67
	T6511	0.67
	F	0.58
	O	0.60
6061	All	1.00

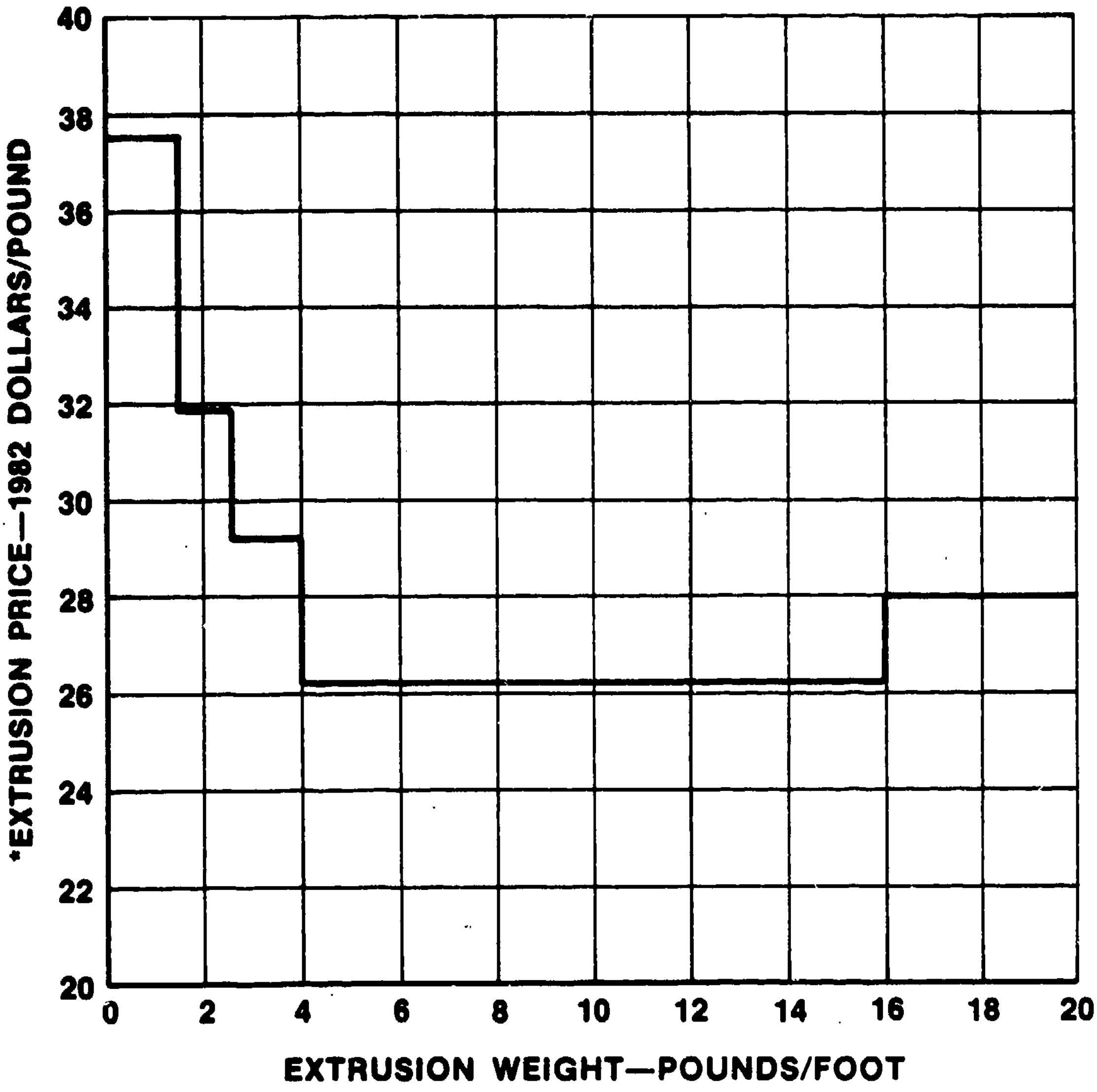
CED-EXTN-2

MATERIAL—EXTRUSION SETUP COST FOR ALUMINUM, TITANIUM & STEEL



CED-EXTN-3

MATERIAL COST—TITANIUM
Ti 6AL-4V



*INCLUDES TEST, INSPECTION, AND EVALUATION (TI&E) COST FOR THE AS-EXTRUDED MATERIAL.

CED-EXTN-4

MATERIAL COSTS - STEEL

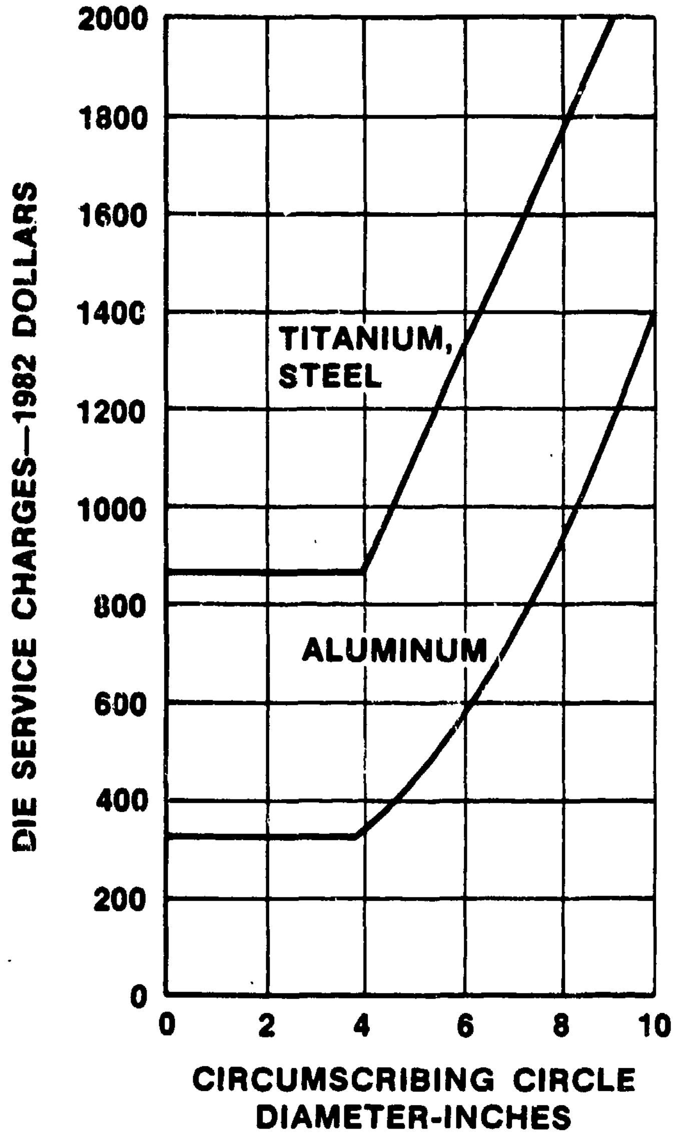
Based upon limited historical cost data in the absence of published price schedules, approximate material costs for steel extrusions are:

	1982 Cost*
Low Alloy Steels 4130, 4140, 4340, 8630	$3.50/Lb
PH13-8Mo CRES	$16.50/Lb

* Includes T*&E cost for the as-extruded material.

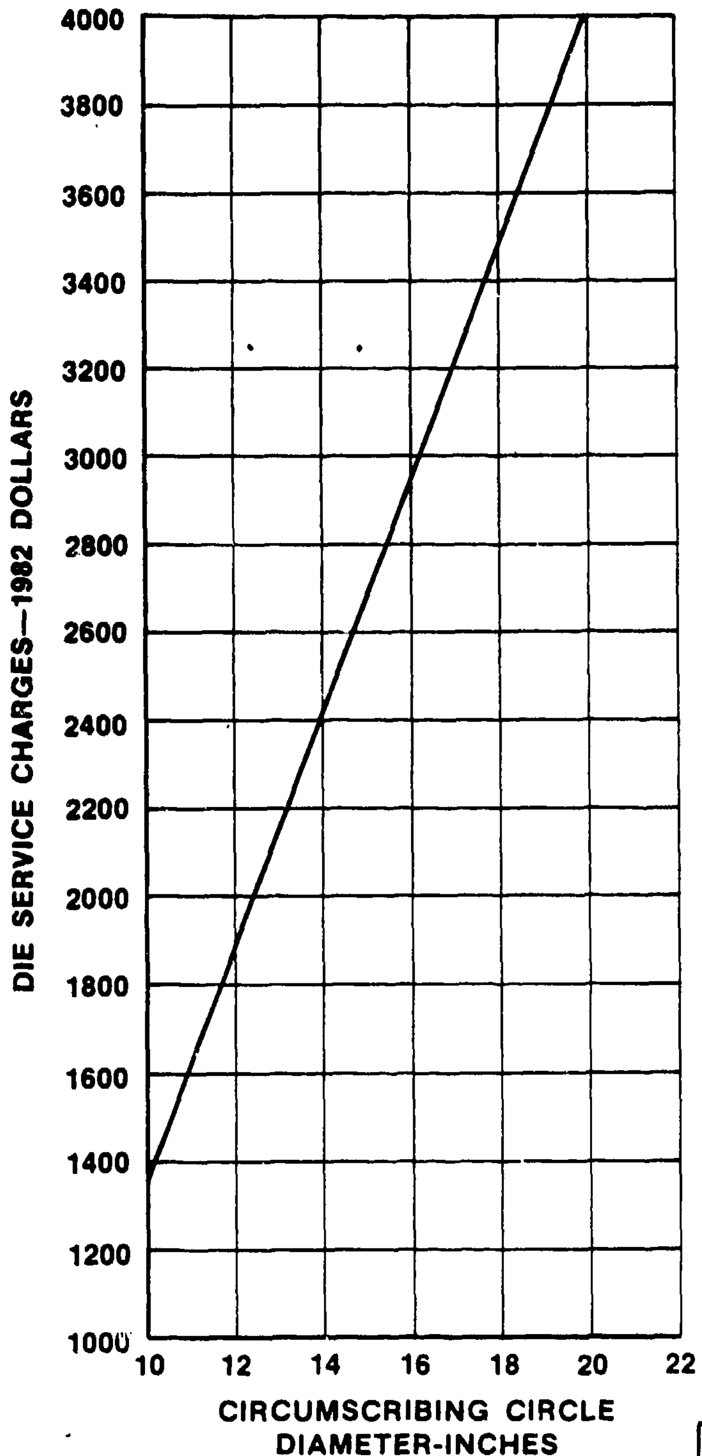
CED-EXTN-5

SUPPLIER NONRECURRING TOOL COST CIRCUMSCRIBING CIRCLE UNDER 10" DIAMETER



CED-EXTN-6

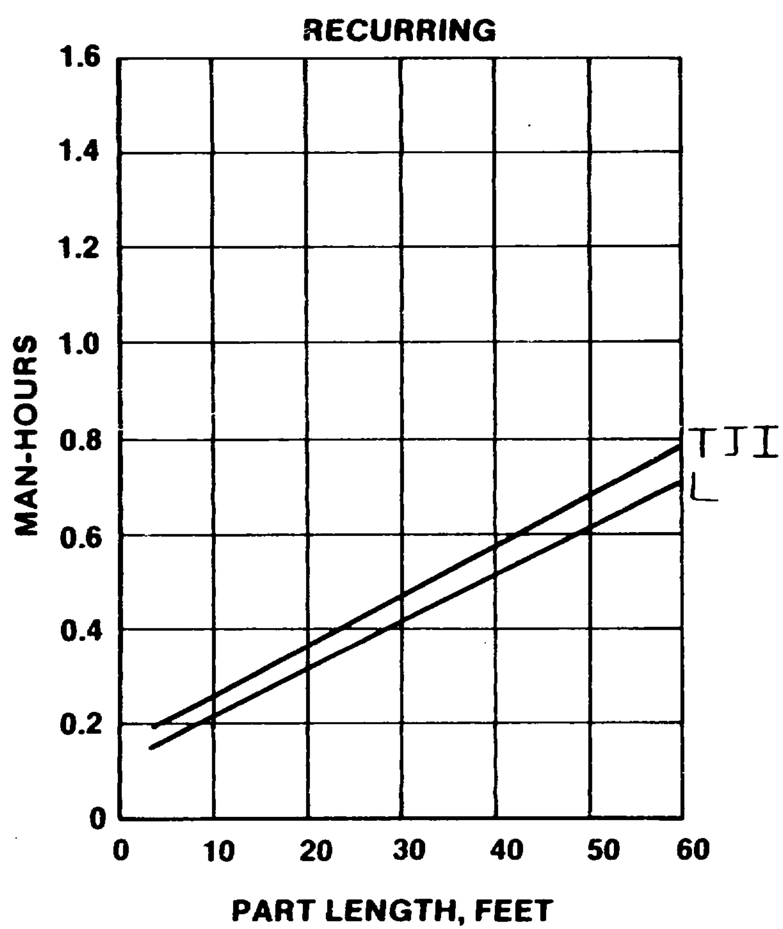
SUPPLIER NONRECURRING TOOL COST FOR LONGITUDINALLY STIFFENED PANELS/SLABS CIRCUMSCRIBING CIRCLE DIAMETER 10"-22"

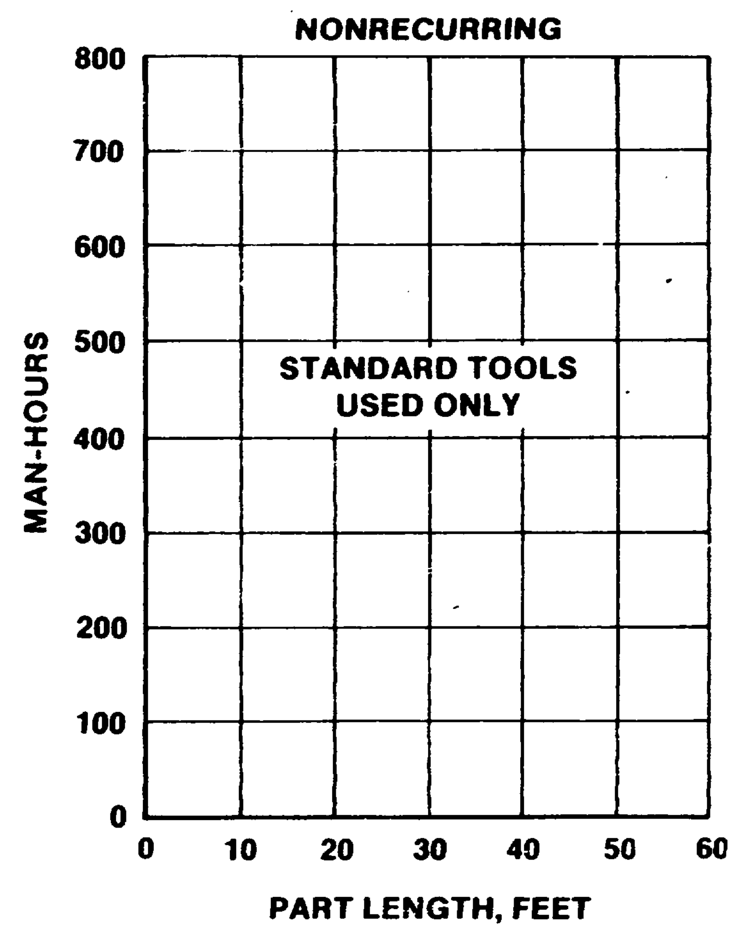


CED-EXTN-7

ALUMINUM EXTRUSIONS
LINEAL SHAPES

STRAIGHT





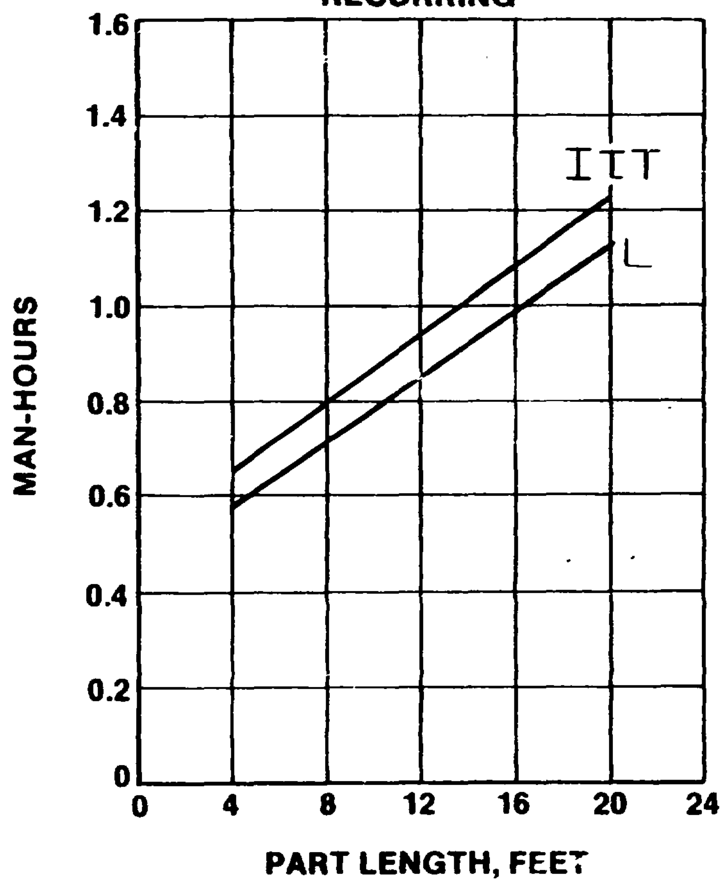
OBTAIN TEST, INSPECTION AND EVALUATION (TI&E) COSTS FROM TI&E SECTION FOR SHEET METAL PARTS

CED-EXTN-8

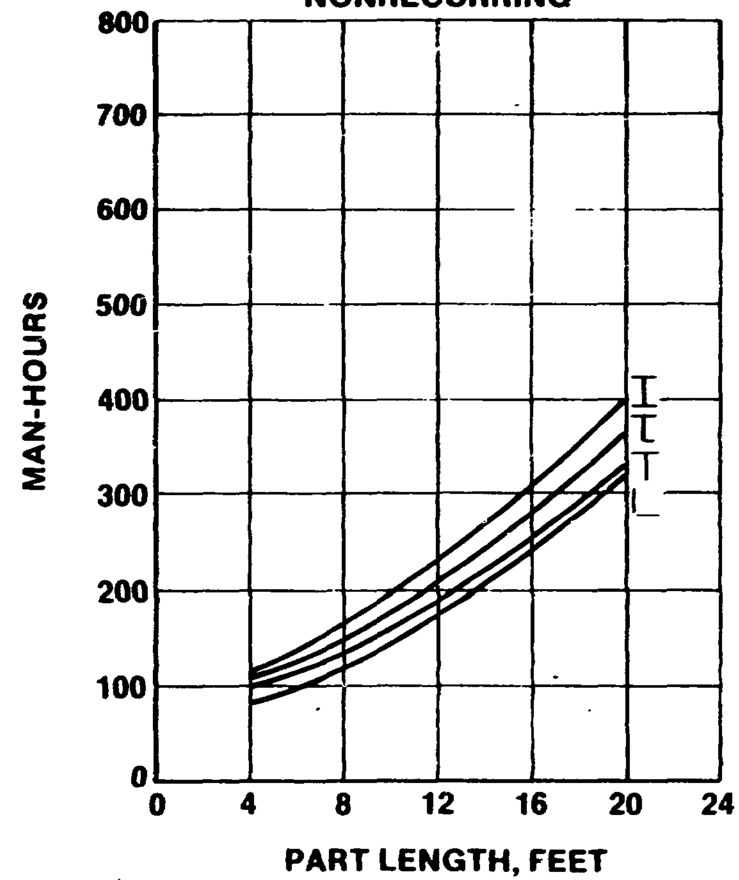
ALUMINUM EXTRUSIONS
LINEAL SHAPES

CYLINDRICALLY OR NON-CYLINDRICALLY CONTOURED

RECURRING



NONRECURRING

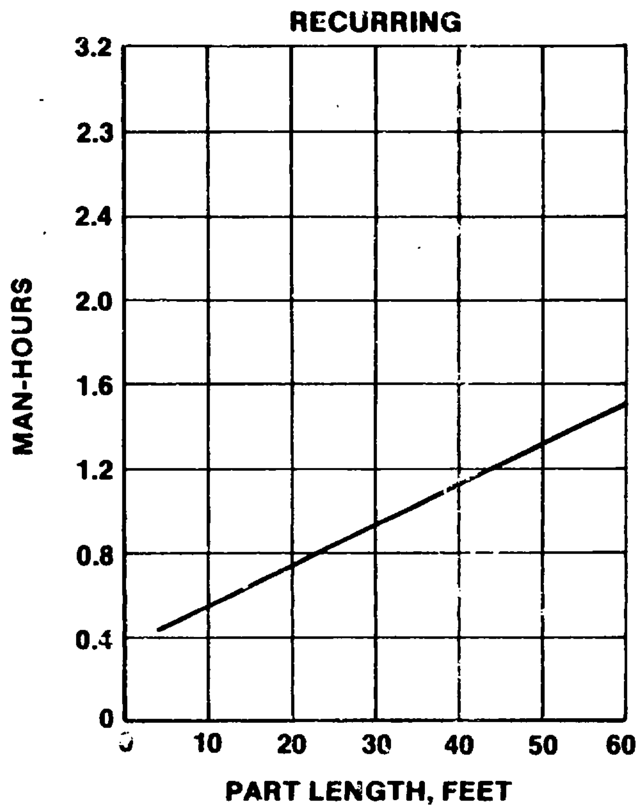


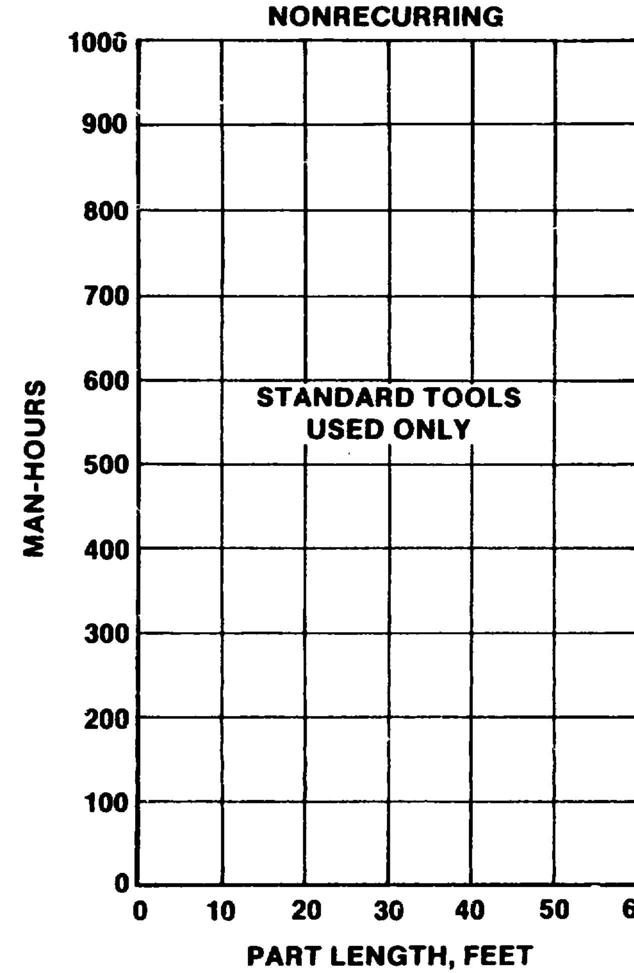
OBTAIN TEST, INSPECTION AND EVALUATION (TI&E) COSTS FROM TI&E SECTION FOR SHEET METAL PARTS

CED-EXTN-9

ALUMINUM EXTRUSIONS
LONGITUDINALLY STIFFENED PANELS/SLABS

STRAIGHT



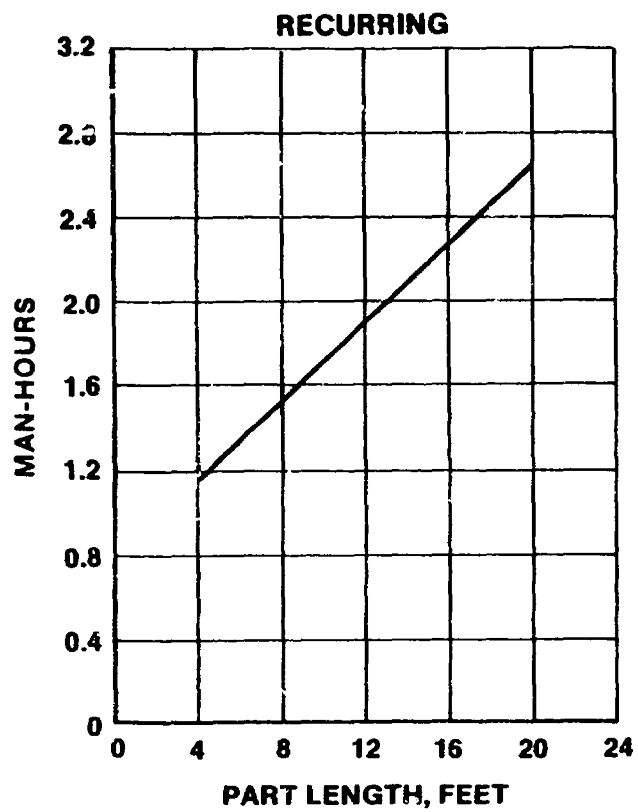


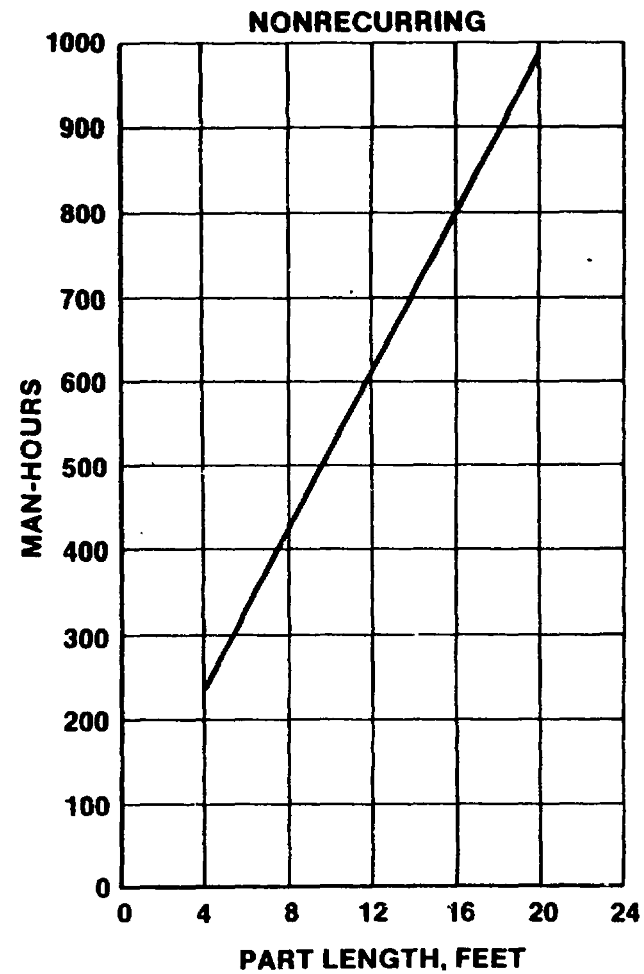
OBTAIN TEST, INSPECTION AND EVALUATION (TI&E) COSTS
FROM TI&E SECTION FOR SHEET METAL PARTS

CED-EXTN-10

ALUMINUM EXTRUSIONS
LONGITUDINALLY STIFFENED PANELS/SLABS

CYLINDRICALLY OR NON-CYLINDRICALLY CONTOURED



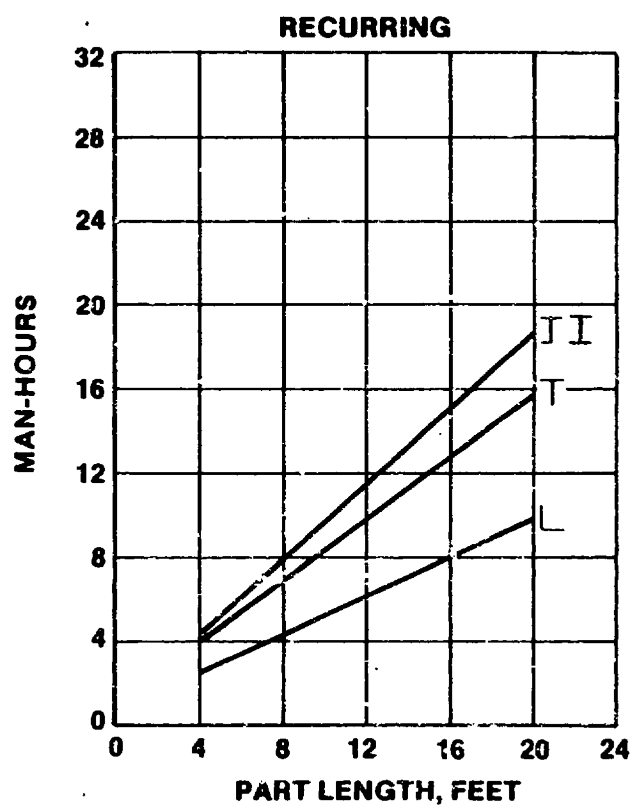


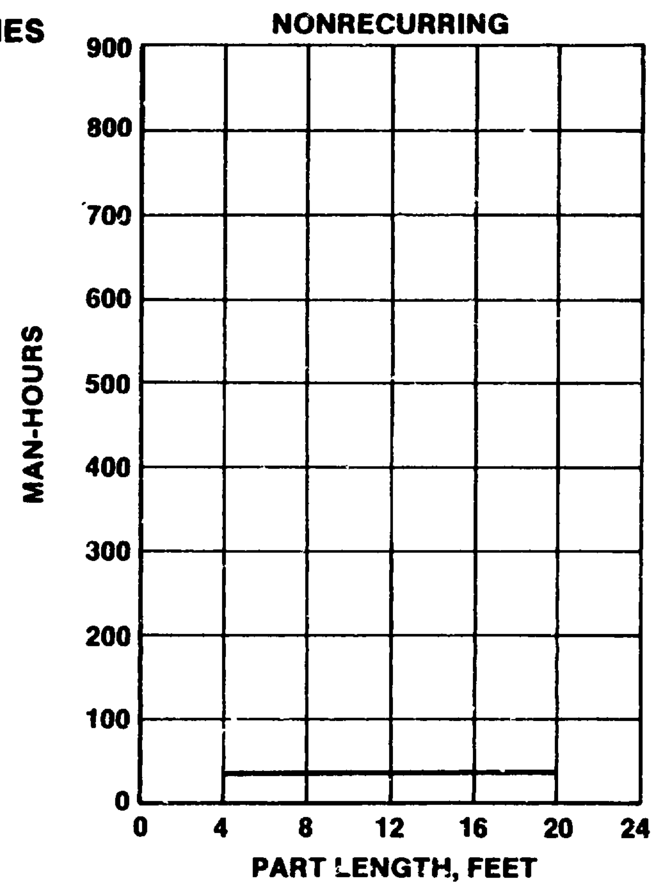
OBTAIN TEST, INSPECTION AND EVALUATION (TI&E) COSTS FROM TI&E SECTION FOR SHEET METAL PARTS

CED-EXTN-11

TITANIUM EXTRUSIONS
LINEAL SHAPES

STRAIGHT
DATA VALID FOR CIRCLE DIAMETER ≤6 INCHES





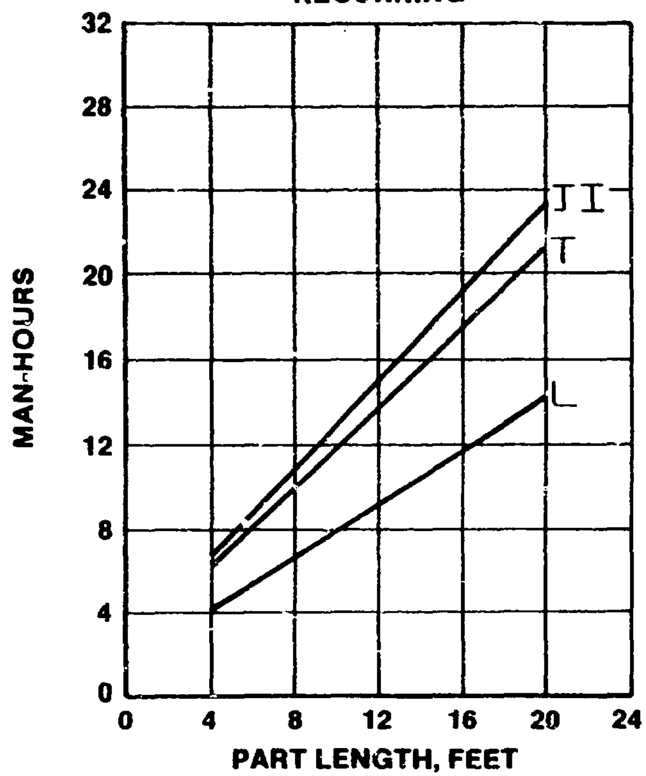
- OBTAIN TEST, INSPECTION AND EVALUATION (TI&E) COSTS FROM TI&E SECTION FOR MACHINED PARTS
- COST INCLUDES MACHINING TO ASSURE CONTAMINATION FREE, SMOOTH SURFACE/EDGE

CED-EXTN-12

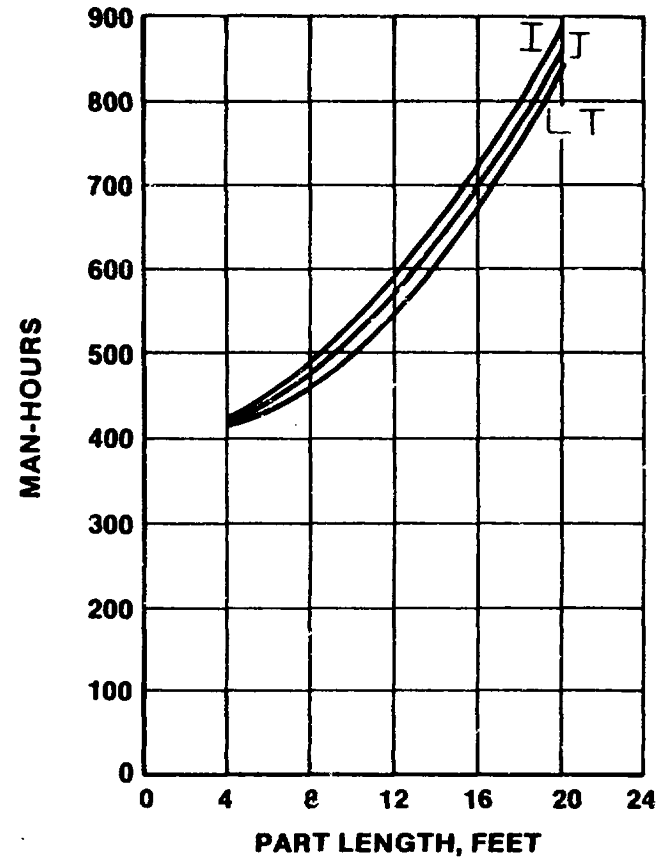
TITANIUM EXTRUSIONS
LINEAL SHAPES

CYLINDRICALLY OR NON-CYLINDRICALLY CONTOURED
DATA VALID FOR CIRCLE DIAMETER ≤6 INCHES

RECURRING



NONRECURRING

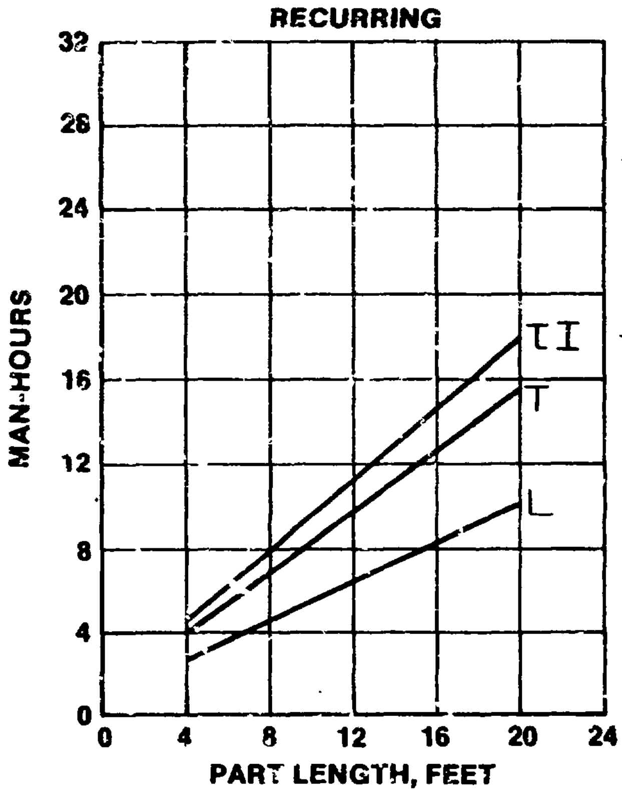


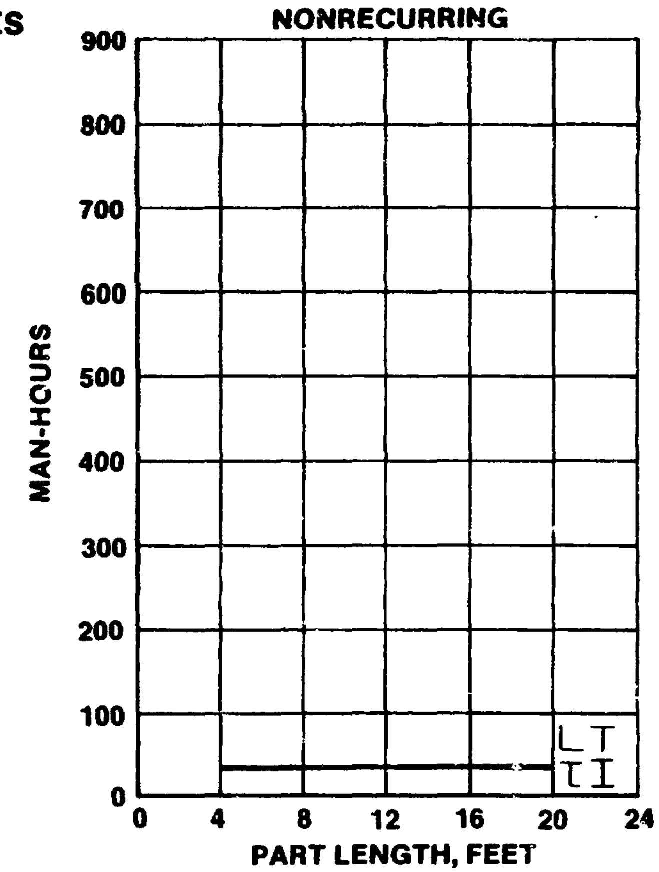
- OBTAIN TEST, INSPECTION AND EVALUATION (TI&E) COSTS FROM TI&E SECTION FOR MACHINED PARTS
- COST INCLUDES MACHINING TO ASSURE CONTAMINATION FREE, SMOOTH SURFACE/EDGE

CED-EXTN-13

STEEL EXTRUSIONS
LINEAL SHAPES

STRAIGHT
DATA VALID FOR CIRCLE DIAMETER ≤6 INCHES



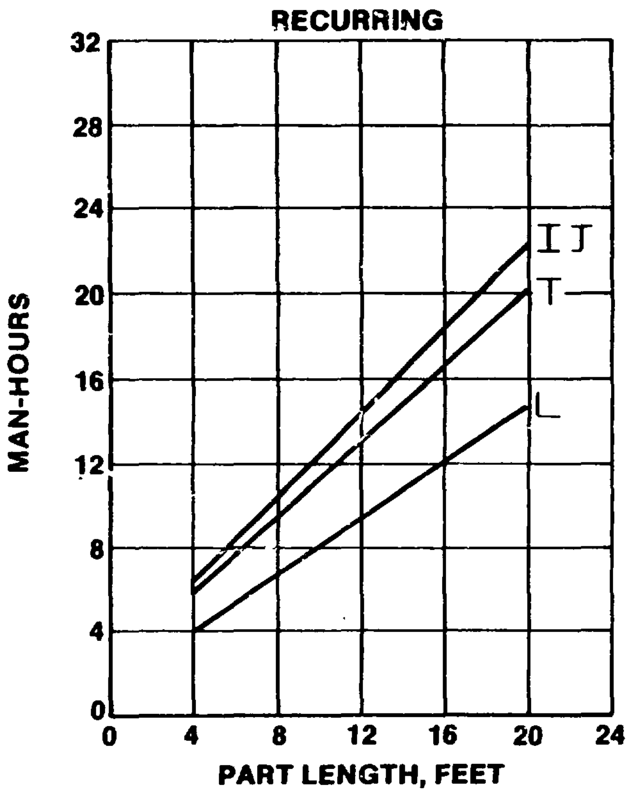


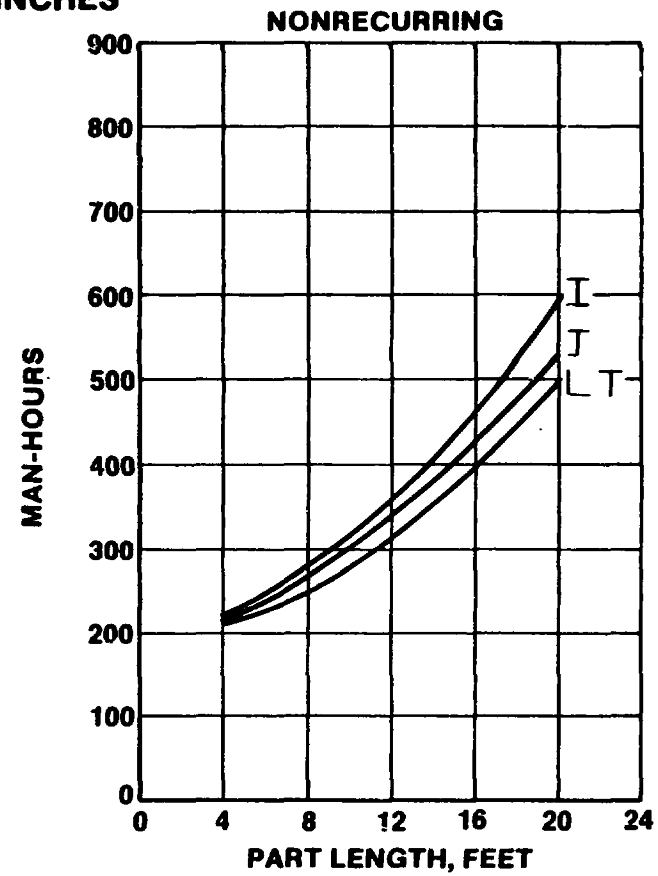
- MULTIPLY MAN-HOURS BY 1.06 WHEN EXTRUDED WEIGHT ≥ 100 POUNDS
- OBTAIN TEST, INSPECTION AND EVALUATION (TI&E) COSTS FROM TI&E SECTION FOR MACHINED PARTS
- COST INCLUDES MACHINING TO ASSURE CONTAMINATION FREE, SMOOTH SURFACE/EDGE

CED-EXTN-14

STEEL EXTRUSIONS
LINEAL SHAPES

CYLINDRICALLY OR NON-CYLINDRICALLY CONTOURED
DATA VALID FOR CIRCLE DIAMETER ≤ 6 INCHES

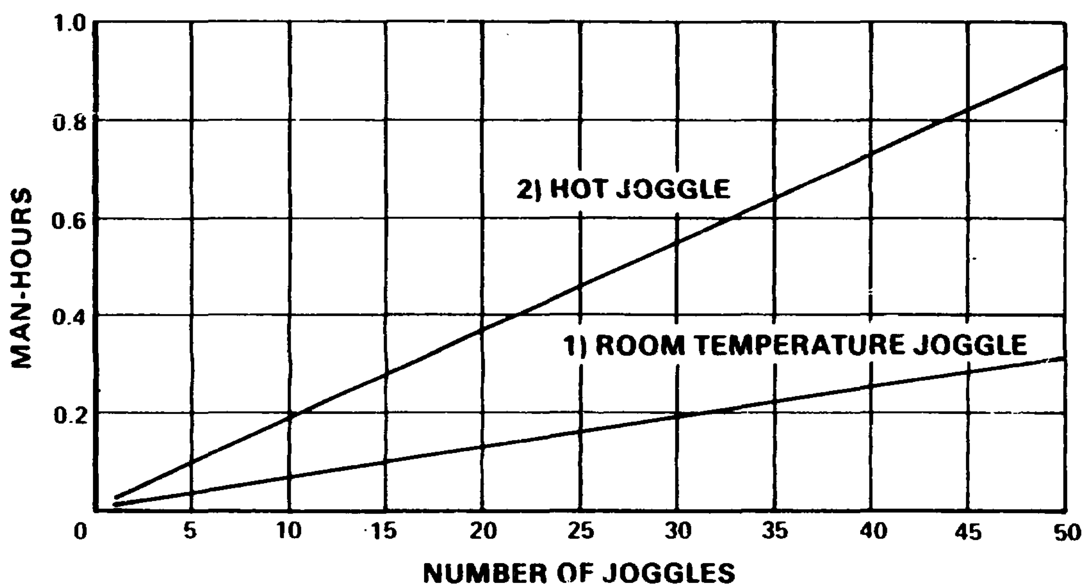




- MULTIPLY MAN-HOURS BY 1.06 WHEN EXTRUDED WEIGHT ≥ 100 POUNDS
- OBTAIN TEST, INSPECTION AND EVALUATION (TI&E) COSTS FROM TI&E SECTION FOR MACHINED PARTS
- COST INCLUDES MACHINING TO ASSURE CONTAMINATION FREE, SMOOTH SURFACE/EDGE

CED-EXTN-15

EXTRUDED LINEAL PARTS JOGGLE RECURRING COST



1) USED FOR ALUMINUM AND STEEL PARTS
2) USED FOR TITANIUM PARTS

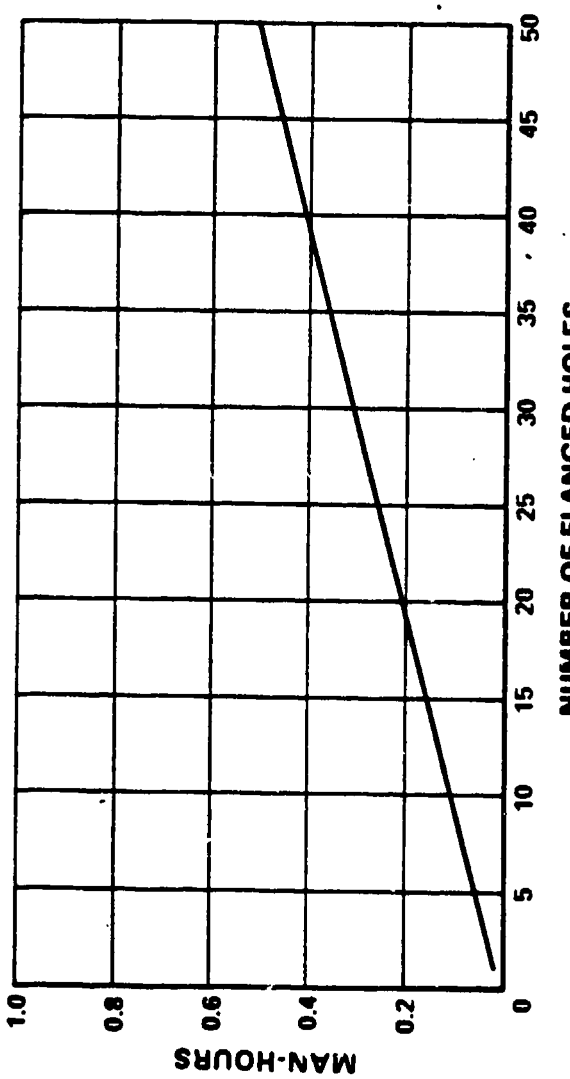
BASED ON USE OF STANDARD TOOLS

DICE-EXTN-1

DICE-EXTN-2

EXTRUDED DISCRETE PARTS
FLANGED HOLE RECURRING COST

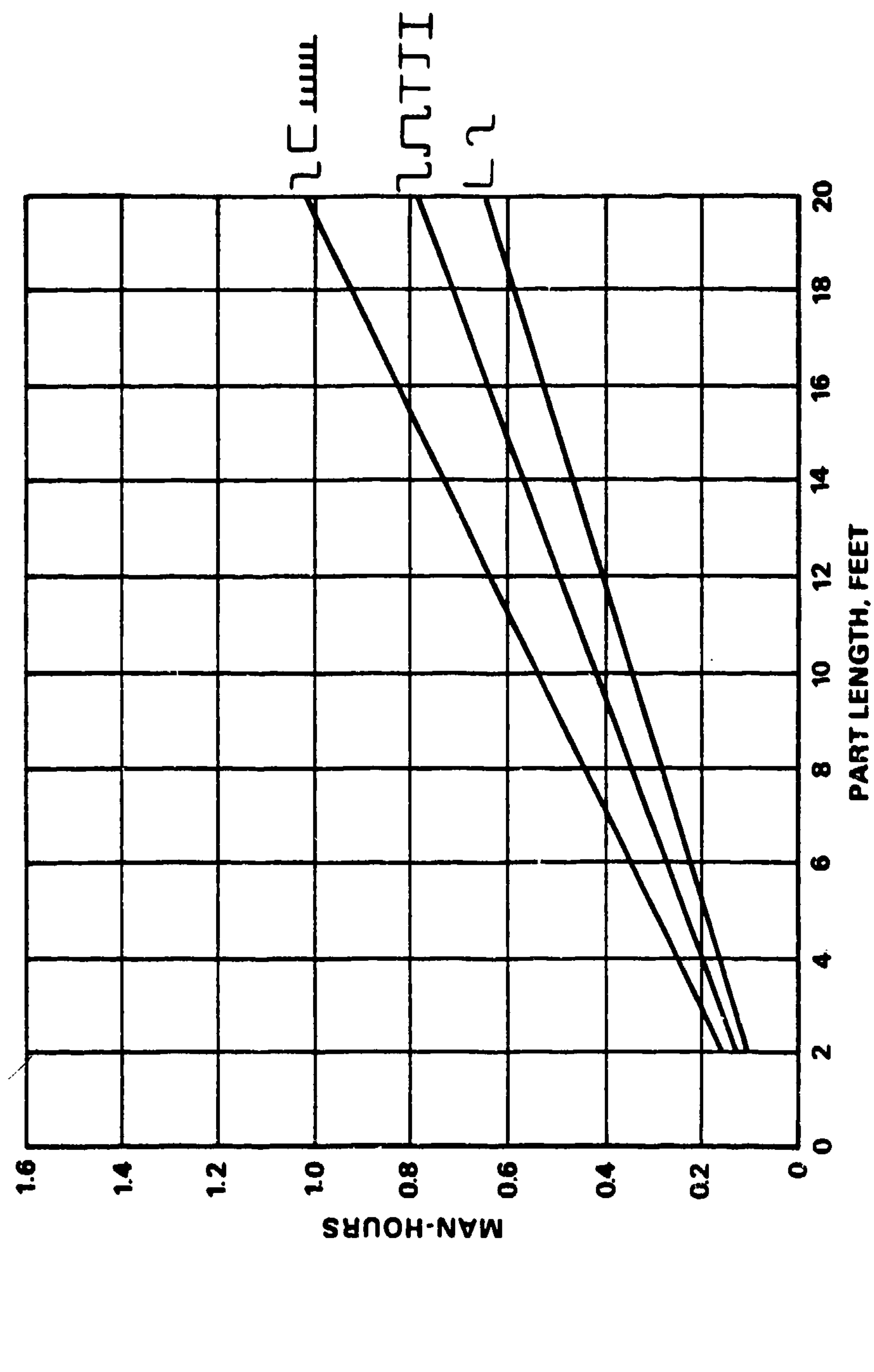
ALUMINUM, TITANIUM AND STEEL



BASED ON USE OF STANDARD TOOLS

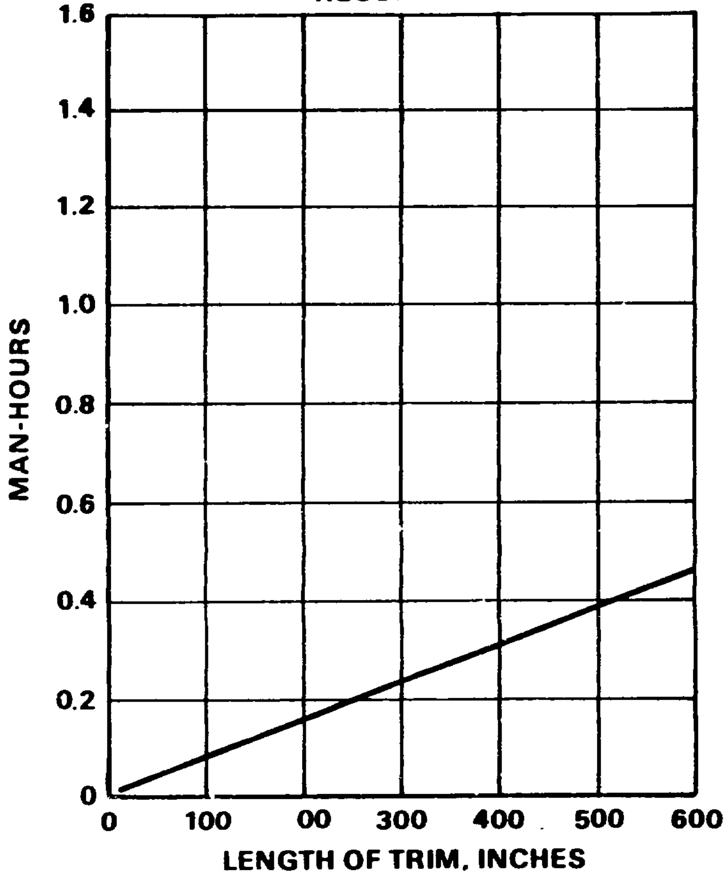
DICE-EXTN-3

ALUMINUM EXTRUSIONS
LINEAL PARTS
SOLUTION HEAT TREAT AND AGE

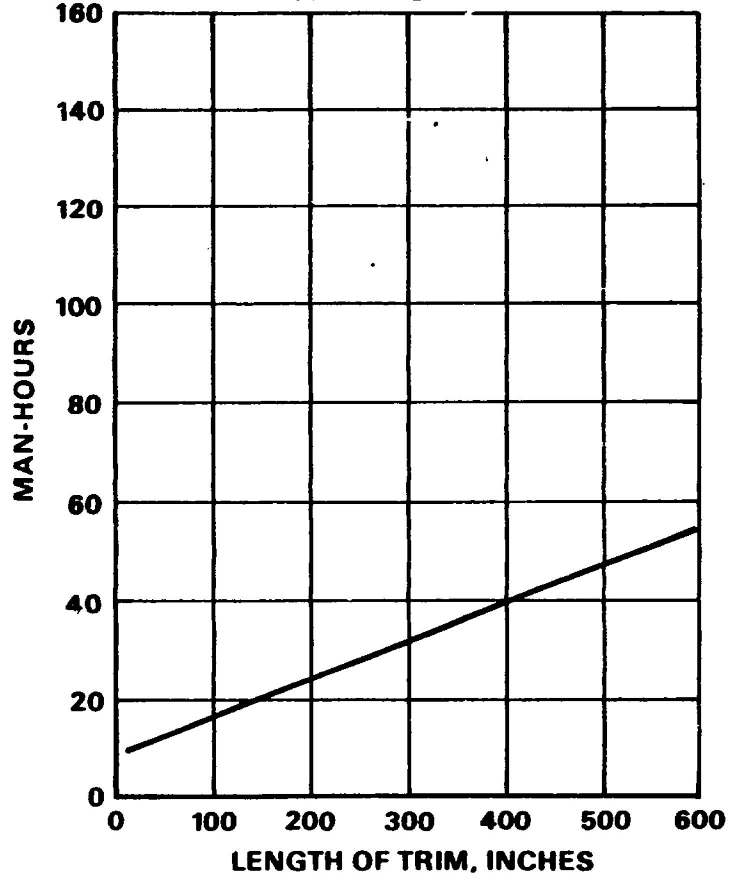


ALUMINUM EXTRUSIONS
LINEAL PARTS
TRIM AFTER FORMING

RECURRING



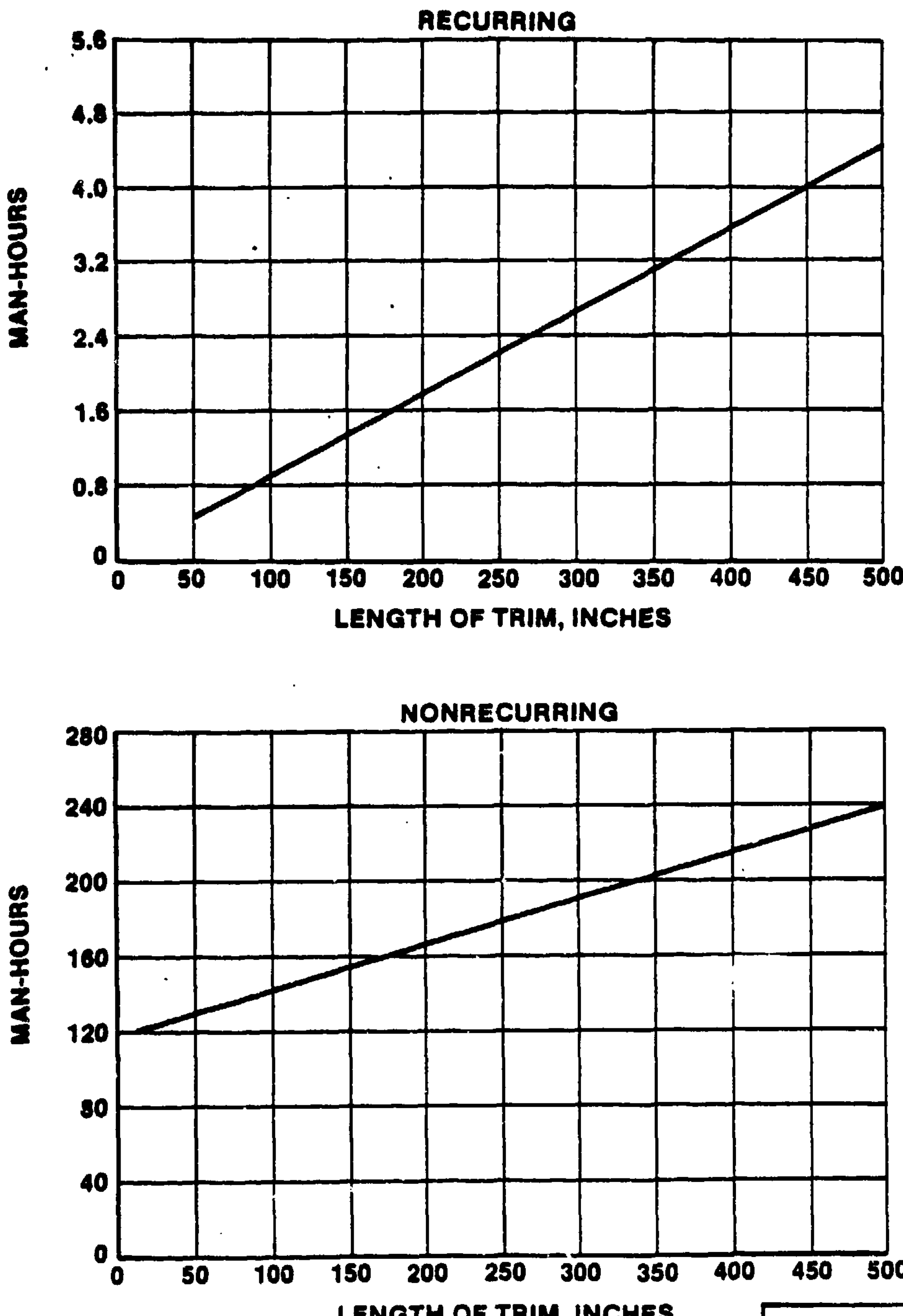
NONRECURRING



NOTE: EXTRAPOLATE TO 600"

DICE-EXTN-4

STEEL OR TITANIUM EXTRUSIONS
TRIM EDGES
STRAIGHT OR CURVED



DICE-EXTN-5

4.4.5 Ground Rules for Extrusions Section

The following General and Detailed Ground Rules for the Extrusions Section were developed to establish the scope of the data required and to establish guidance to MC/DG application. Ground rules are necessary and important as they promote understanding, ensure consistency, uniformity, and accuracy in generating and integrating data into the formats.

4.4.5.1 General Ground Rules

The general ground rules are categorized under the following major groupings:

(a) Extruded Discrete Parts
(b) Materials
(c) Manufacturing Methods
(d) Facilities
(e) Data Generation - Recurring Costs
(f) Data Generation - Nonrecurring Costs
(g) Support Function Modifiers.

(a) Extruded Discrete Parts

(1) The extruded aerospace discrete parts selected will be representative of common structural parts required for both small and large aircraft. The parts will be selected such that a base part forms the foundation which the designer can modify as required to achieve the desired discrete part of structural configuration. Extruded discrete parts include stringers, longerons, frame rib and spar caps representing elements of major airframe structural subassemblies.

(2) The discrete parts will be selected, where possible, to develop data for more than one manufacturing method. The data thereby enables the designer, using the MC/DG, to determine the most cost-competitive manufacturing method in trade-studies.

(3) The selected discrete parts will be defined and dimensioned to adequately display the effect on part cost of DICE, e.g., joggles, trim, and lightening holes. Facility limitations

will be used in determining the dimension ranges for the discrete part considered.

(4) Support function modifiers will be excluded but can be handled in the preferred way by the aerospace company using the MC/DG.

(b) Materials

(1) The alloys selected for the discrete parts will be representative of the range of those more commonly used in the industry to enable a uniform data base to be established. The materials included are:

- Aluminum
- Titanium
- Steel.

(2) Raw material costs for the parts will be included in the MC/DG formats.

(3) Material cost of nonrecurring tooling will not be included, except when this cost impacts a design decision, for example, for manufacturing certain discrete parts in titanium.

(c) Manufacturing Methods

(1) Only conventional manufacturing methods required to produce the extruded parts in the configurations selected will be considered. No emerging manufacturing methods will be evaluated.

(2) A production, in contrast to a prototype environment will be assumed for the extruded discrete parts.

(3) To generate an effective data base for each selected part, a factory operational sequence for each applicable manufacturing method will be established reflecting the most economical means of fabrication. This standardized sequence will be used by each airframe company team member to determine the part cost (man-hours).

(4) Tool families required to manufacture the various parts will be identified on the data collection forms.

(d) Facilities

(1) Only standard manufacturing facilities, available to the airframe industry, will be considered.

(e) Data Generation - Recurring Costs

(1) Recurring and nonrecurring man-hour data will be generated for the complete process of parts fabrication and will include all hands-on-factory direct labor operations from raw stock through forming, heat treatment, priming, etc., to storage of the part in preparation for assembly into the airframe.

(2) The base-part cost (man-hours) will be generated for each part. The base-part cost will represent the sum of all standard hours associated with each part.

(3) DICE, requiring added operations, will be treated as separate cost elements, and therefore, will not be included in the base-part cost.

(4) The quantity for which the base-part cost will be determined is unit 200 and will be based on team member learning curves.

(5) Labor cost data will be presented in man-hours. Material costs will be presented in 1982 dollars. The data submitted to BCL will be the base-part cost plus the costs (man-hours) of DICE associated with the discrete part design.

(6) To demonstrate the impact of set up costs, lot releases of 25 parts will be used.

(7) Set up time (man-hours) is the total set up time required to complete the part. The set up time will be amortized over the lot size and added to run times to obtain the base-part cost (man-hours).

(8) Recurring tooling costs (tool maintenance, planning, etc.) will not be included.

(9) In developing cost data for parts, each participating company will utilize its own proprietary learning curves.

(10) The part cost, as derived by each airframe company, will be normalized by BCL to reflect an industry team average value for each discrete part and range of dimensions.

(11) For proprietary reasons, realization factors (including PF&D), standard hours, and other business sensitive information employed at team member companies will not be included in the analysis on the data sheets or MC/DG formats.

(12) No data provided by any team member will be disclosed to other team members, agencies, or to the public without the expressed approval of the team member.

(f) Data Generation - Nonrecurring Costs

(1) Tool fabrication costs will be generated for each part type. In addition, tool design and tool planning costs will be evaluated with respect to their impact, to determine whether they should be included or omitted for the three material types.

(2) The cost of production tooling, if included, will be restricted to contract or project tools only, for presentation in the MC/DG.

(3) Nonrecurring tooling, including extrusion die, costs (NTRC) generated by the team companies will be normalized by BCL for presentation in the MC/DG.

(g) Support Function Modifiers

(1) Additional effort other than factory labor, such as manufacturing engineering, will be excluded from the part cost data supplied to BCL. These modifiers may be included later by users of the MC/DG.

4.4.5.2 Detailed Ground Rules

The detailed ground rules are categorized under the following major groupings:

(a) Materials
(b) Size and Shape
(c) Tolerances
(d) Discrete Parts
(e) Manufacturing Methods
(f) Facilities
(g) Contract Tooling.

(a) Materials

(1) The materials selected for sheet-metal discrete parts are:
- Aluminum: 2024, 7075 and 6061
- Titanium: 6Al-4V (annealed)
- Steel: PH13-8 CRES and 4340.

(2) Treatment required for any of these materials to increase physical properties or to improve formability will be indicated on the part sketches, data collection forms, and formats.

(3) For aluminum, recent price sheets will be used. For titanium and steel, airframe company historical data will be used.

(b) Size and Shape

(1) Maximum circle size: 24"

(2) Typical shapes will include:
- Angles
- Tees
- J's
- I's
- Ribbed panel extruded flat

(3) Hollow extrusions not to be considered.

(c) Tolerances

(1) Industry accepted mill tolerances for extrusions and for discrete parts fabricated from extrusions will be considered.

(2) Parts will be manufactured to a tolerance of $\pm$ 0.030 inch. The cost impact of tighter or more relaxed tolerances is considered to be a designer-influenced cost element (DICE).

(d) Discrete Parts

(1) Drawings of the extruded aerospace discrete parts showing configurations, dimensions, joggles, holes, trim, heat treatment, etc., will be prepared so that each team member may estimate base standard hours in a consistent manner.

(2) The cross-sectional dimensions of the lineal shapes will correspond to a maximum envelope of 6 inches diameter.

(3) The operational sequence necessary to produce each part, as required by the detail drawings, will include every operation required to fabricate the part by the manufacturing method being evaluated, i.e., from the blank to completion ready for the storeroom and assembly into the airframe.

(4) To facilitate trade-off studies, the discrete parts and MC/DG formats will indicate any thermal and/or chemical processing required such as heat treatment and anodizing, respectively, and also painting, prior to assembly, as specified on the detail drawing.

(e) Manufacturing Methods

(1) Forming methods used to fabricate the respective parts will be specified on part size matrices accompanying each drawing and on the data collection forms.

(2) Where more than one manufacturing technology will be candidates to fabricate a discrete part, data will be generated for each method to reveal the comparative cost relationships to the designer.

(f) Facilities

(1) The types of forming equipment utilized in the fabrication of the parts will be those listed in the part size matrix accompanying each extruded discrete part drawing.

(g) Contract Tooling

(1) Because of nonuniformity of tool nomenclature, each team member company will indicate (on the data collection forms) the tool family required to fabricate each discrete part. The nomenclature shown on the forms will be supplemented with information providing a complete tool description, i.e., Drill Press Fixture (DPF).

(2) Tools to be included will be those required to manufacture the the tools, as well as those to make and check the parts, i.e., production check tools.

(3) The average hours per tool type, individual tool estimate, etc., will be determined in accordance with standard procedures for determining cost at the facilities of each team member.

4.5 Casting Section

This section contains format selection aids, identification of the types of parts analyzed for data to determine the manufacturing man-hour data, examples of how the data are utilized in airframe design and a set of formats generated. These formats include cost-driver effects (CDE), cost estimating data (CED), and designer-influenced cost elements (DICE).

4.5.1 Format Selection Aids

Format selection aids are presented to provide the user with a building-block approach to determine manufacturing cost data for alternative designs or processes. The designer can review the format selection trees and identify those areas that have an impact on his design. The formats provide cost-driver effects (CDE) for qualitative guidance to lowest cost and cost-estimating data (CED) in man-hours for conducting trade-off studies.

FORMAT SELECTION AID

CASTINGS
COST DRIVER EFFECTS

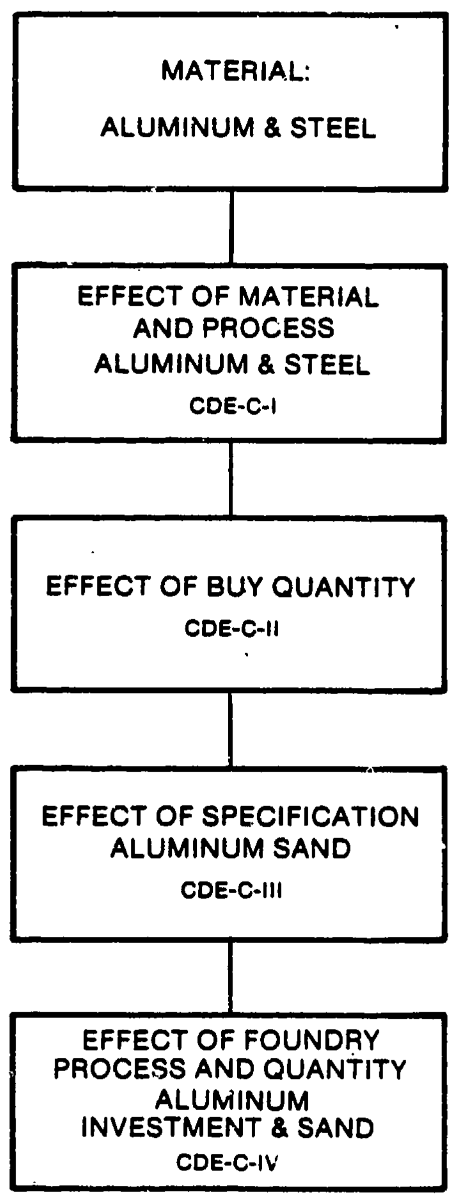
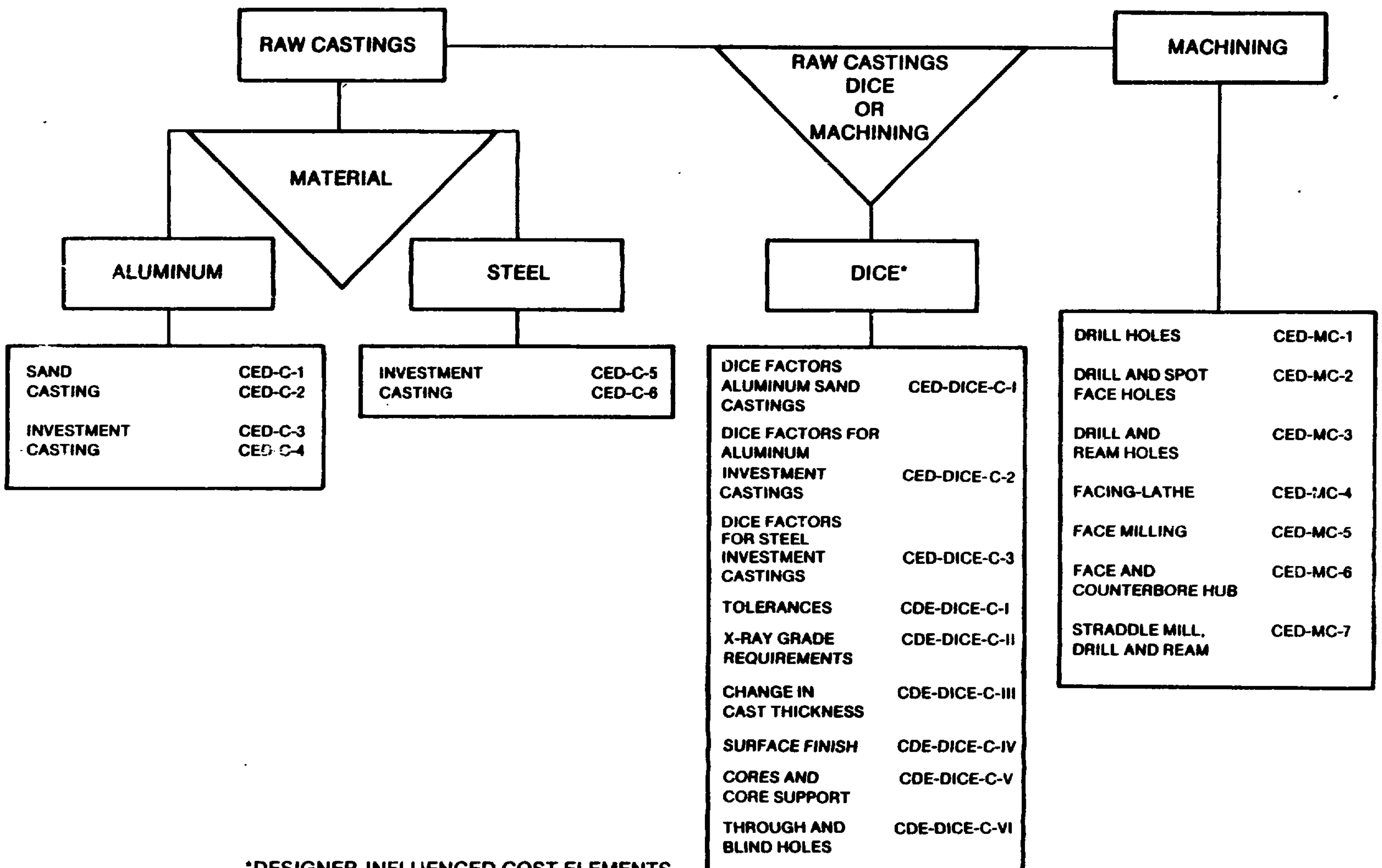


FIGURE 4.5-1

FORMAT SELECTION AID
CASTINGS



*DESIGNER-INFLUENCED COST ELEMENTS

FIGURE 4.5-2

FORMAT SELECTION AID

MACHINING OF CASTINGS

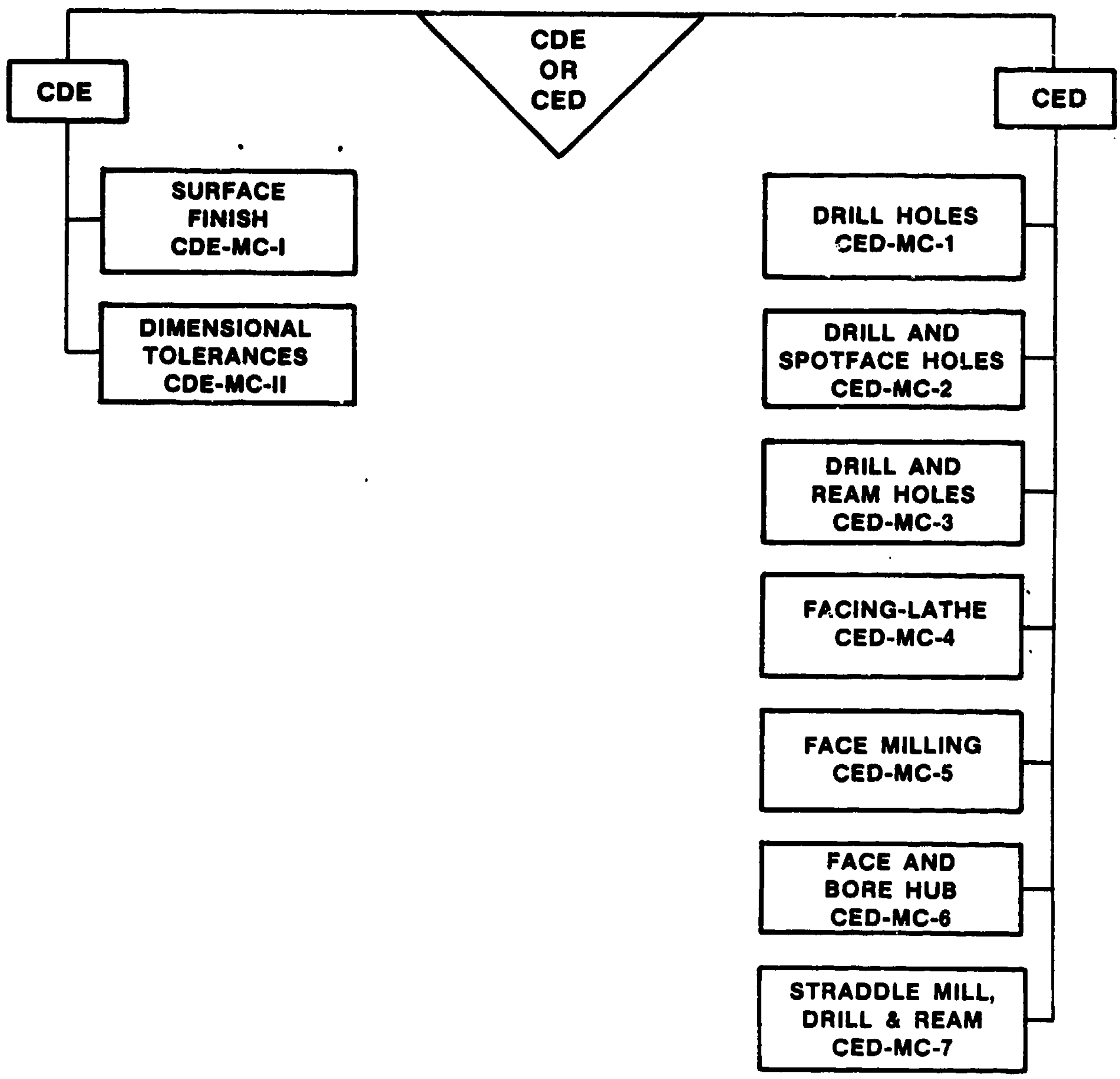


FIGURE 4.5-3

4.5.2 Example of Utilization

This example demonstrates how the data generated are utilized on a specific design problem. The example shows how to identify applicable formats, how to extract data from the formats, and provides a discussion on how the data are used to determine the part cost in man-hours or dollars. The MC/DG cost worksheet can be used to record the cost data for easy reference and to determine the total program cost (Figure 4.3-3). Specific worksheets for casting appear as Tables 4.5-2 and 4.5-3 (Machining of Castings).

4.5.2.1 Utilization Example for Bell Crank

Problem Statement

Determine the cost (1980 dollars) for the aluminum bell crank shown in Figure 4.5-4. Cost elements are: Cost elements are:

- Base casting cost
- Designer-Influenced Cost Elements (DICE)
- Test, Inspection and Evaluation (TI&E) cost of raw casting
- Cost of machining the casting to final dimensions.

The casting has a box volume of 144 in.^{3}. The order will be for 100 units, Class I castings, produced to meet MIL-A-21180. Both sand and investment castings are to be considered.

Procedure

The following procedures are used to determine the bell crank costs for investment castings.

Sand Casting:

1. Utilize the Format Selection Aids for Castings, Machining of Castings, and Castings Test, Inspection and Evaluation (TI&E) to determine the formats needed. In this case, the required formats (included in this section on the pages shown) are:

   CED-C-1 (Fig. 4.5-5)
   CED-DICE-C-1 (Fig. 4.5-6)
   CDE-C-II (Fig. 4.5-7)
   CED-TI&E-C-1 (Fig. 4.5-8)
   CED-C-2 (Fig. 4.5-9)
   CED-MC-2 (Fig. 4.5-10)
   CED-MC-5 (Fig. 4.5-11)
   CED-MC-7 (Fig. 4.5-12)
   CED-C-3 (Fig. 4.5-13)
   CED-DICE-C-2 (Fig. 4.5-14)
   CDE-C-II (Fig. 4.5-15)
   CED-TI&E-C-1 (Fig. 4.5-16)
   CED-C-4 (Fig. 4.5-17)
   CED-MC-1 (Fig. 4.5-18)
   CED-MC-3 (Fig. 4.5-19)

2. Obtain the base casting cost by reading box volume of 144 in.^{3} on the MIL-A-21180 base casting cost line of Format CED-C-3 (Fig. 4.5-13): $90.

3. From CED-DICE-C-2 (Fig. 4.5-14), read the DICE factor table for a Class I casting: 1.0 + 0.10 = 1.1 DICE factor.

4. To determine the lot quantity factor, read the effect of a buy quantity of 100 units on casting cost from Format CDE-C-II (Fig. 4.5-15): 0.93.

5. From Format CED-TI&E-C-1 (Fig. 4.5-16), read the TI&E cost for a box volume of 144 in.^{3}: $16.

6. Read the nonrecurring tooling cost for a box volume of 144 in^3 from Format CED-C-4 (Fig. 4.5-17): $5,000. NOTE: Some companies have a policy to include a check fixture (ICF). Estimated cost is equal to 30 percent of the base tooling cost: $5,000 x 0.30 = $1,500.

7. Read hole drilling cost (man-hours) from CED-MC-1 (Fig. 4.5-18). Three 0.25-in. diameter holes at 0.018 man-hour/hole = 0.054 man-hour.

8. Read drill and ream hole cost (man-hours) from CED-MC-3 (Fig. 4.5-19): Two 0.25-in. diameter holes at 0.023 man-hour/hole = 0.046 man-hour.

9. From CED-MC-1 (Fig. 4.5-18), read that drill hole tooling cost (man-hours) is equal to a base of 32 man-hours plus two man-hours/hole: 32 + (3 x 2) = 38 man-hours.

10. From CED-MC-3 (Fig. 4.5-19), read that drill and ream tooling cost (man-hours) is equal to a base of 32 man-hours plus two man-hours/hole: 32 + (2 x 2) = 36 man-hours.

11. Determine recurring base casting cost, which is the sum of the base casting cost ($90) times the DICE factor (1.10) and lot quantity factor (0.93), plus TI&E cost ($16): $90 x 1.10 x 0.93 = $92 + $16 = $108.

12. Determine nonrecurring base casting cost, which is the sum of the foundry tooling costs ($5,000) and the ICF ($1,500): $5,000 + $1,500 = $6,500.

13. Determine recurring machining costs, which are the sum of the drilling man-hours (0.054) and drill and ream man-hours (0.046), times the learning curve factor for a 90 percent learning curve (Table 4.5-1) (1.30), times an assumed hourly wraparound rate of $50: (0.054 + 0.046) x 1.30 x $50 = $6.50.

14. Determine nonrecurring machining costs, which are the sum of drill tooling man-hours (38) and drill and ream tooling man-hours (36) times an assumed rate of $50: (38 + 36) x $50 = $3,700.

15. Determine total recurring costs for 100 units, which are the sum of the base casting recurring costs ($108) and machining recurring costs ($6.50) times 100: $108 + $6.50 = $114.50 x 100 = $11,450.

16. Determine total nonrecurring costs, which are the sum of the base casting nonrecurring cost ($6,500) and the machining nonrecurring costs ($3,700): $6,500 + $3,700 = $10,200.

17. Determine total cost for 100 units, which is the sum of the total recurring cost ($11,450) and the total non-recurring cost($10,200): $11,450 + $10,200 = $21,650.

18. Determine total average cost per unit, which equals the total cost($21,650) divided by the quantity (100): $21,650/100 = $217/unit.

The results obtained show that the investment casting is less costly to produce than the sand casting (see following example) for the projected quantity of 100 units. The cost savings is $31 per unit.

Investment Casting:

1. Utilize the Format Selection Aids for Castings, Machining of Castings, and Castings Test, Inspection and Evaluation (TI&E) to determine formats needed.

2. Obtain the base casting cost by reading box volume of 144 $in.^3$ on the MIL-A-21180 base casting cost line of Format CED-C-1 (Figure 4.5-5): $50.

3. From CED-DICE-C-1 (Fig. 4.5-6), read the DICE factors for a Class I casting (0.10) and poorly supported cores (0. 20): 1.0 + 0.10 + 0.20 = 1.30 DICE factor.

4. To determine the lot quantity factor, read the effect of a buy quantity of 100 units on casting cost from Format CDE-C-II (Figure 4.5-7): 0.93.

5. From Format CED-TI&E-C-1 (Fig. 4.5-8), read the TI&E cost for a box volume of 144 $in.^3$: $16.

6. Read the nonrecurring tooling cost for a box volume of 144 $in.^3$ from Format CED-C-2 (Fig. 4.5-9): $3,200. NOTE: Some companies have a policy to include a check fixture (ICF). Estimated cost is equal to 30 percent of the base tooling cost: $3,200 x 0.30 = $960.

7. Read drilling and spotfacing cost (man-hours) from CED-MC-2 (Fig. 4.5-10): Three 0.25-in. diameter holes @ 0.22 = 0.66 man-hour.

8. Read face milling cost (man-hours) for 3 $in.^2$ of milled area from CED-MC-5 (Fig. 4.5-11): 0.02 man-hour

9. Read clevis-straddle mill, drill, and ream cost (man-hours) from CED-MC-7 (Figure 4.5-12):
   (a) 1.50 "A" dimension = 0.14 man-hour
   (b) 0.74 "A" dimension = 2 @ 0.12 = 0.24 man-hour.

10. From CED-MC-2 (Fig. 4.5-10), read that drill and spot face tooling cost (man-hours) is equal to a base of 32 man-hours plus 2 man-hours for each three holes: 32 + (3 x 2) = 38 man-hours.

11. From CED-MC-5 (Fig. 4.5-11), read face milling tooling cost (man-hours): 57 man-hours.

12. From CED-MC-7 (Fig. 4.5-12), read that straddle mill, drill and ream tooling cost (man-hours) is equal to a base of 60 man-hours plus 15 man-hours for each of three clevises: 60 + (3 x 15) = 105 man-hours.

13. Determine recurring base casting cost, which is the sum of the base casting cost ($50) factored by DICE (1.30) and lot quantity (0.93) plus the TI&E cost: $50 x 1.30 x 0.93 = $60.

14. Determine nonrecurring base casting cost, which is the sum of the foundry tooling cost ($3,200) plus the ICF ($960): $3,200 + $960 = $4,160.

15. Determine recurring costs for machining casting, which are the sum of the man-hours for drilling and spotfacing (0.066); face milling (0.02); and clevis straddle milling, drilling, and reaming (0.38), times the learning curve factor for a 90 percent learning curve (Table 4.5-1) (1.30) times an assumed hourly wraparound rate of $50: (0.066 + 0.02 + 0.38) x 1.30 x $50 = $30.

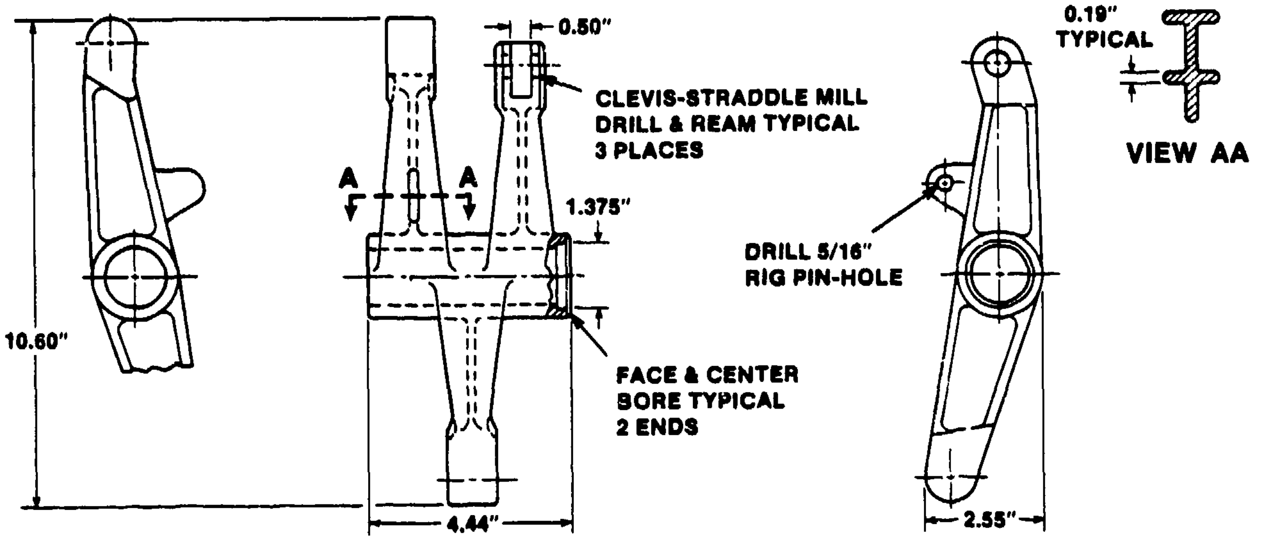
16. Determine nonrecurring machining costs, which are the sum of the man-hours for drill and spot-face tooling (38), mill tooling (57), and clevis straddle mill, drill, and ream tooling (105), times an assumed hourly wraparound rate of $50: (38 + 57 + 105) x $50 = $10,000.

17. Determine total recurring costs for 100 units, which are the sum of the recurring costs for the base casting ($76) and the machining recurring costs ($30), times 100: $76 + $30 = $106 x 100 = $10,600.

18. Determine total nonrecurring costs, which are the sum of the base casting nonrecurring cost ($4,160) and the machining nonrecurring cost ($10,000): $4,160 + $10,000 = $14,160.

19. Determine the total cost for 100 units, which is equal to the sum of the total recurring costs ($10,600) and the total nonrecurring costs ($14,160): $10,600 + $14,160 = $24,760.

20. Determine total average cost per unit, which equals the total cost ($24,760) divided by the quantity (100): $24,760/100 = $248/unit.



BELLCRANK
365 T6 SAND CAST QQ-A-601

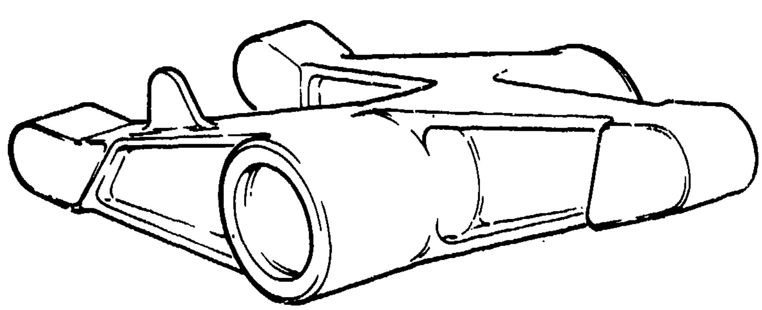
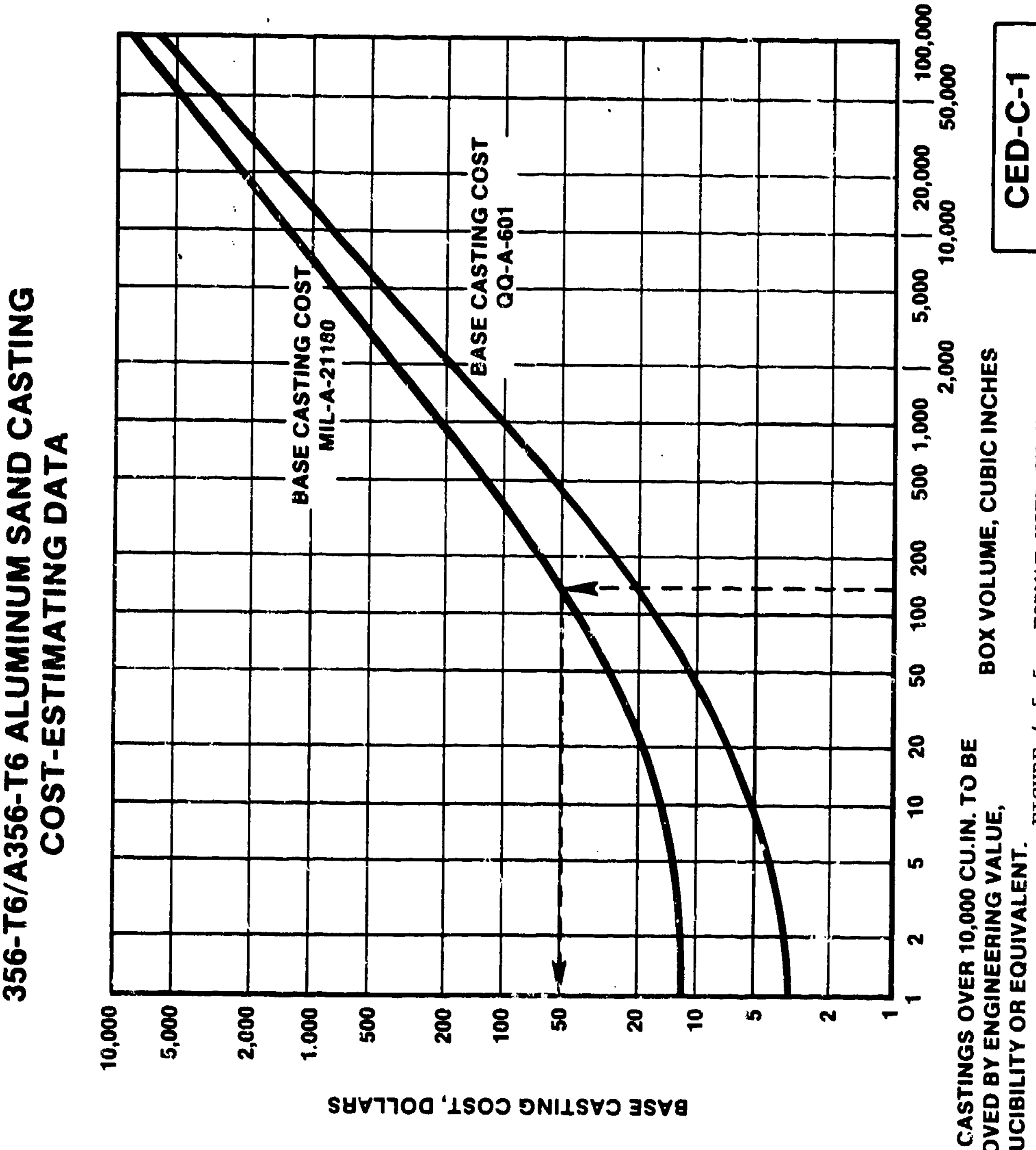


FIGURE 4.5-4. CAST PART ANALYZED



NOTE: SAND CASTINGS OVER 10,000 CU.IN. TO BE APPROVED BY ENGINEERING VALUE, PRODUCIBILITY OR EQUIVALENT.

FIGURE 4.5-5. FORMAT USED IN EXAMPLE

DICE FACTOR FOR ALUMINUM SAND CASTINGS COST ESTIMATING DATA

NOTE: DICE FACTOR EQUAL TO ONE PLUS SUM OF ALL APPLICABLE DICE FACTOR INCREMENTS IN TABLE. RESULTING DICE FACTOR USED TO MODIFY BASE CASTING COST.

DESIGN FEATURE	DICE FACTOR INCREMENT
CASTING CLASSIFICATION	
Class II	—
Class I	0.10
X-RAY GRADE	
D	—
D with C Areas	—
C	0.05
C with B Areas	0.20
B	0.50
TOLERANCE — LENGTH/WIDTH	
±0.003"/in. ±0.03" min	—
±0.0025"/in. ±0.025" min	0.10
±0.002"/in. ±0.02" min	0.20
TOLERANCES — THICKNESS	
±0.03"	—
±0.025"	0.10
±0.02"	0.20
SURFACE FINISH	
C50	—
C25	—
C20	0.15
FILLET RADII	
R = Wall Thickness	—
R = 1/2 Wall Thickness	0.10
LOCAL THICK AREAS	
Under 0.25"	—
0.25" to 0.50"	—
0.50" to 1.0"	0.05
1.0" to 2.0"	0.20
Over 2.0"	0.30
THROUGH HOLES	
None	—
Length/Diam. < 4	0.10
Length/Diam. 4-8**	0.25
BLIND HOLES	
None	—
Length/Diam. < 4	0.45
Length/Diam. 4-8**	0.60
NUMBER OF CORES	
1-3	0.10
4-7	0.30
8-11	0.50
12 UP	0.80
CORES	
Well Supported	—
Poorly Supported	0.20
SLENDERNESS RATIO (L/W OR T)	
L/W or L/T < 6	—
L/W or L/T 6-12	0.10
L/W or L/T > 12	0.25

**Consult Value or Producibility for L/D Ratios Over 8

FIGURE 4.5-6. FORMAT USED IN EXAMPLE

CED-DICE-C-1

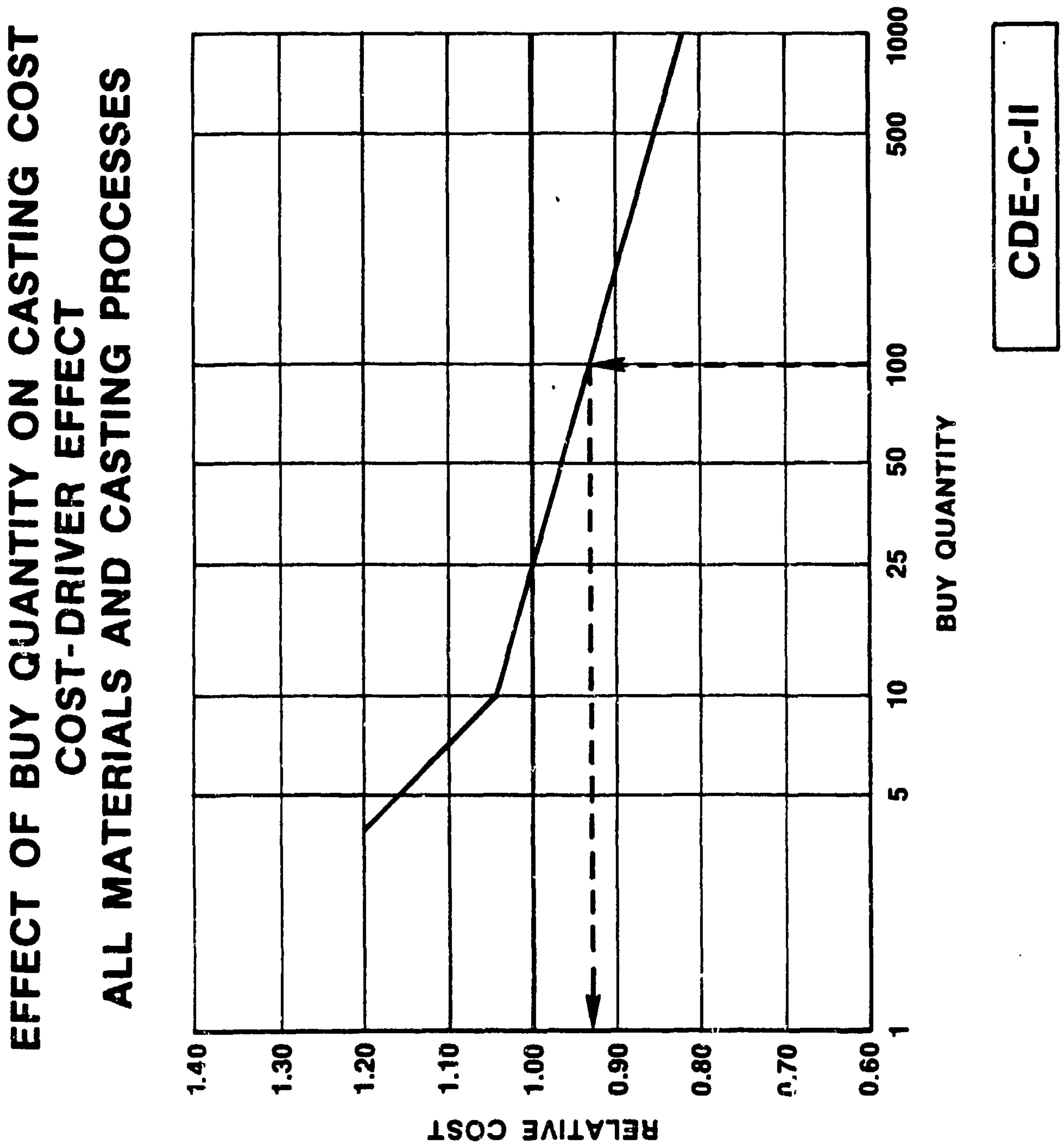


FIGURE 4.5-7. FORMAT USED IN EXAMPLE

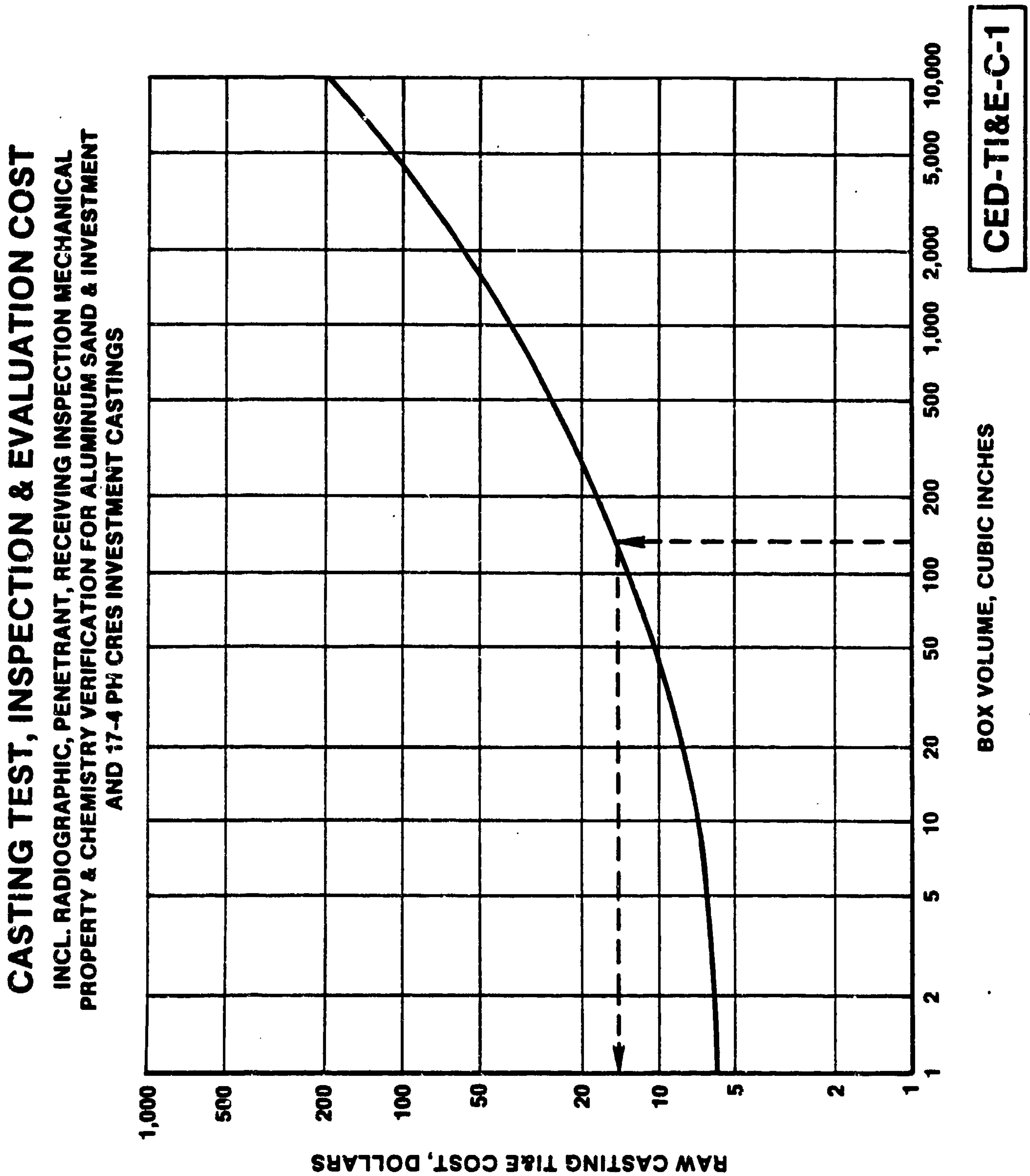


FIGURE 4.5-8. FORMAT USED IN EXAMPLE

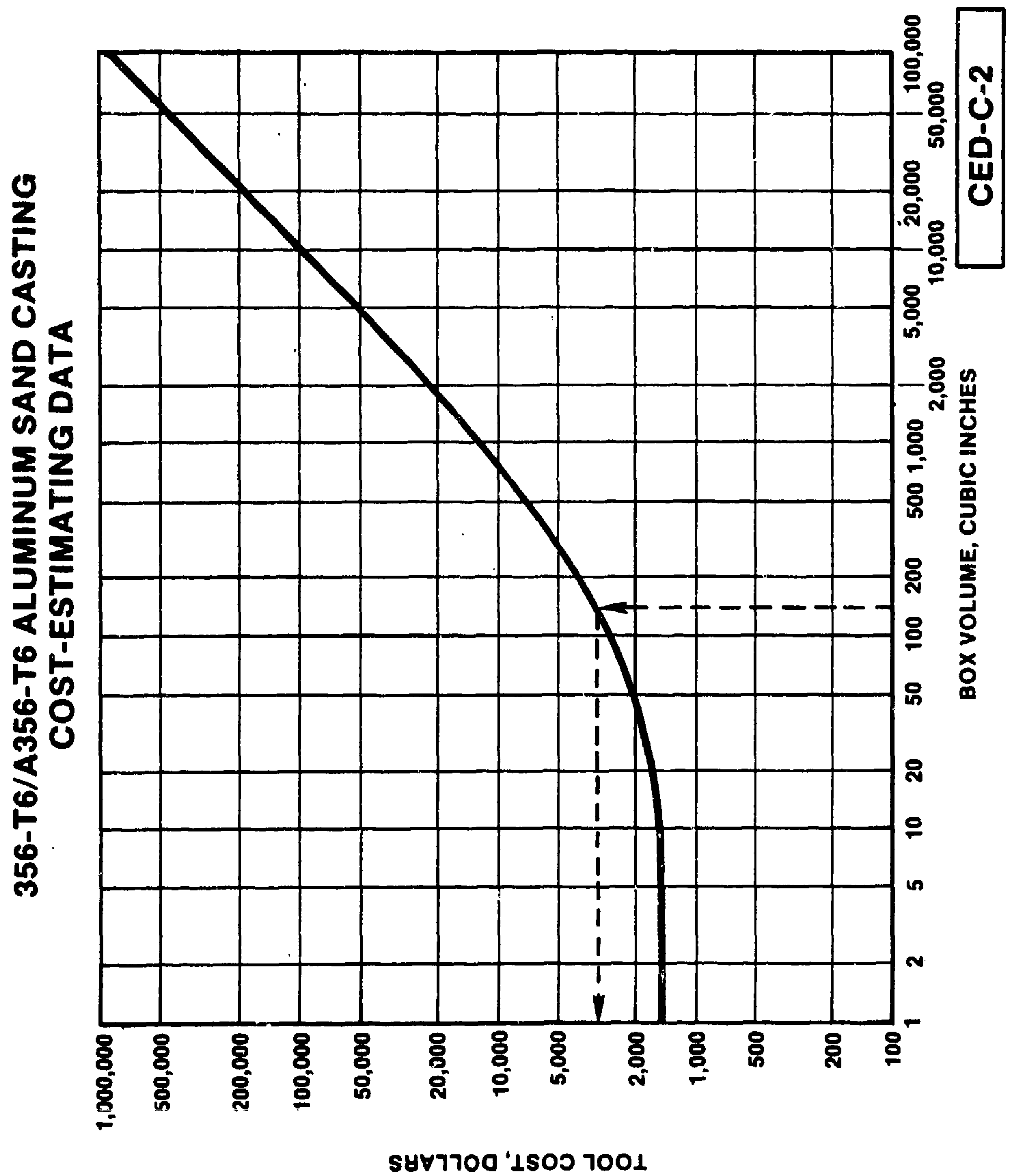
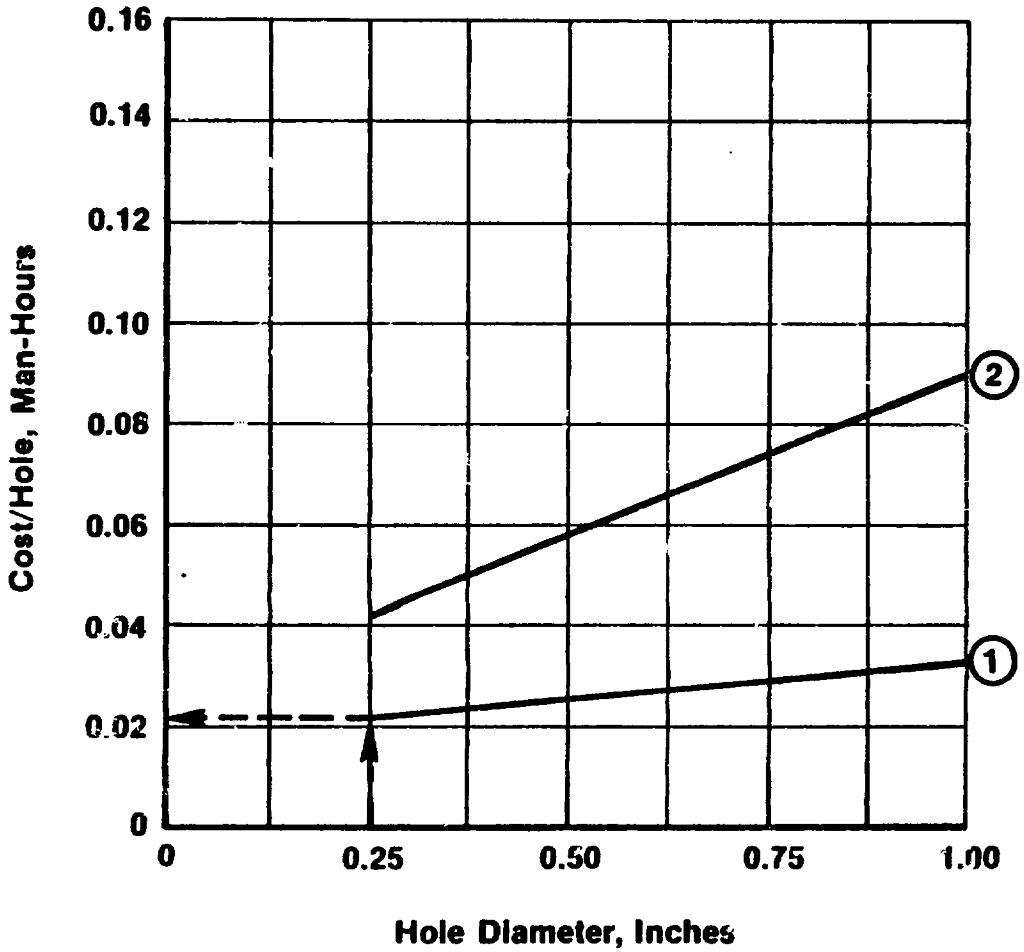


FIGURE 4.5-9. FORMAT USED IN EXAMPLE

MACHINING OF CASTINGS
DRILL AND SPOTFACE HOLES



Nonrecurring Tool Cost

NRTC = (32 + 2N) Man-Hours

Where N is the number of holes in the pattern.

1. 356-T6 Aluminum
2. 17-4 PH CRES

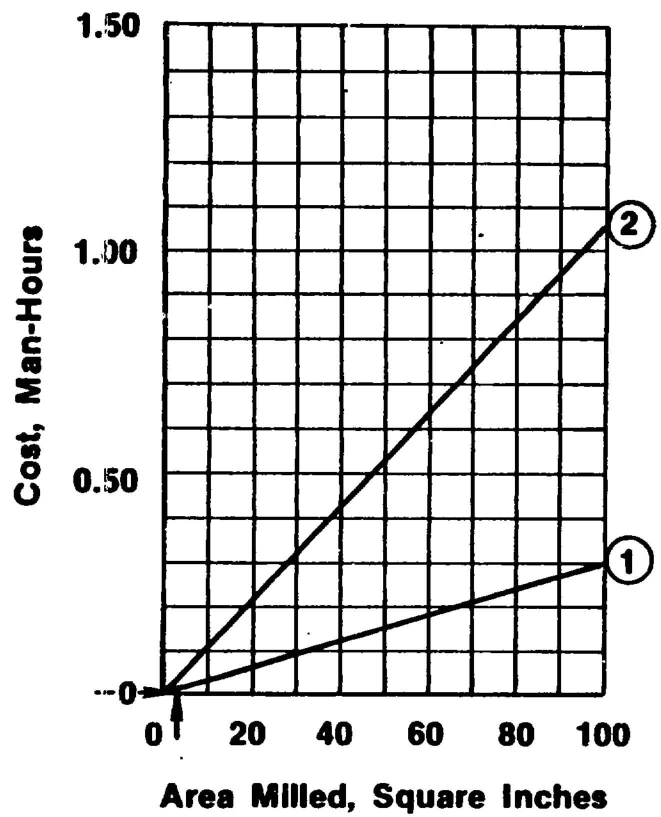
Cost/Part = (Cost/Hole • N) Man-Hours

Cost data is valid for hole depths up to twice the hole diameter.

CED-MC-2

FIGURE 4.5-10. FORMAT USED IN EXAMPLE

MACHINING OF CASTINGS
FACE MILLING



Nonrecurring Tool Cost
NRTC = 57 Man-Hours

(1) 356/A 356-T6 Aluminum

(2) 17-4PH CRES

Step 1 — Determine the face milling cost for <u>each</u> surface machined.

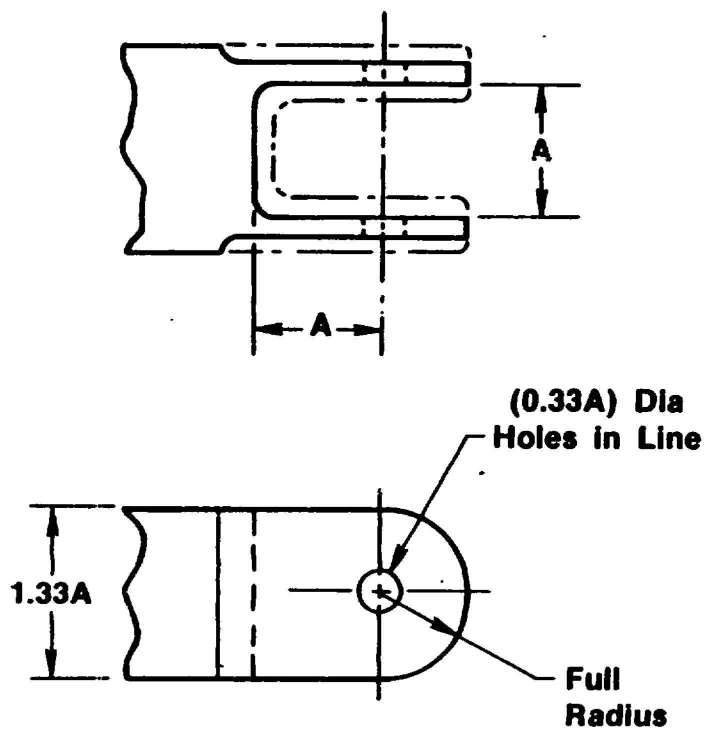
Step 2 — Add the milling costs obtained in Step 1.

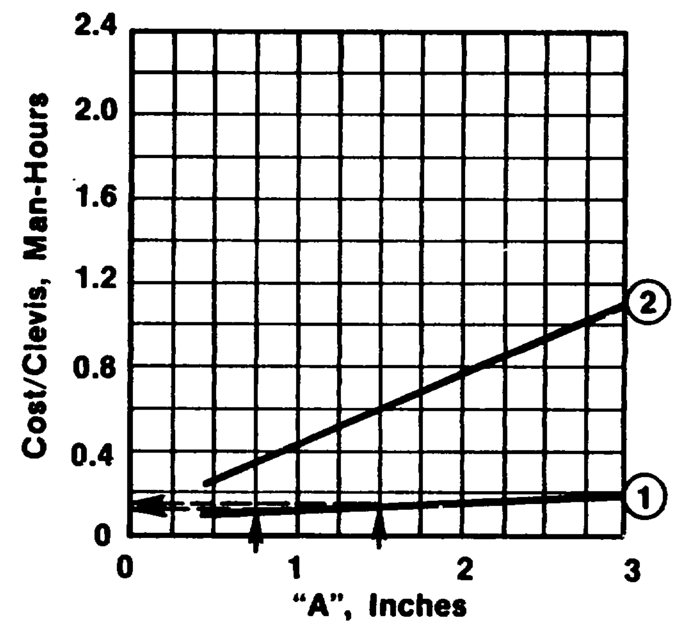
Step 3 — Obtain NRTC above.

CED-MC-5

FIGURE 4.5-11. FORMAT USED IN EXAMPLE

MACHINING OF CASTINGS
STRADDLE MILL, DRILL & REAM





Nonrecurring Tool Cost
NRTC = (60 + 15N) Man-Hours

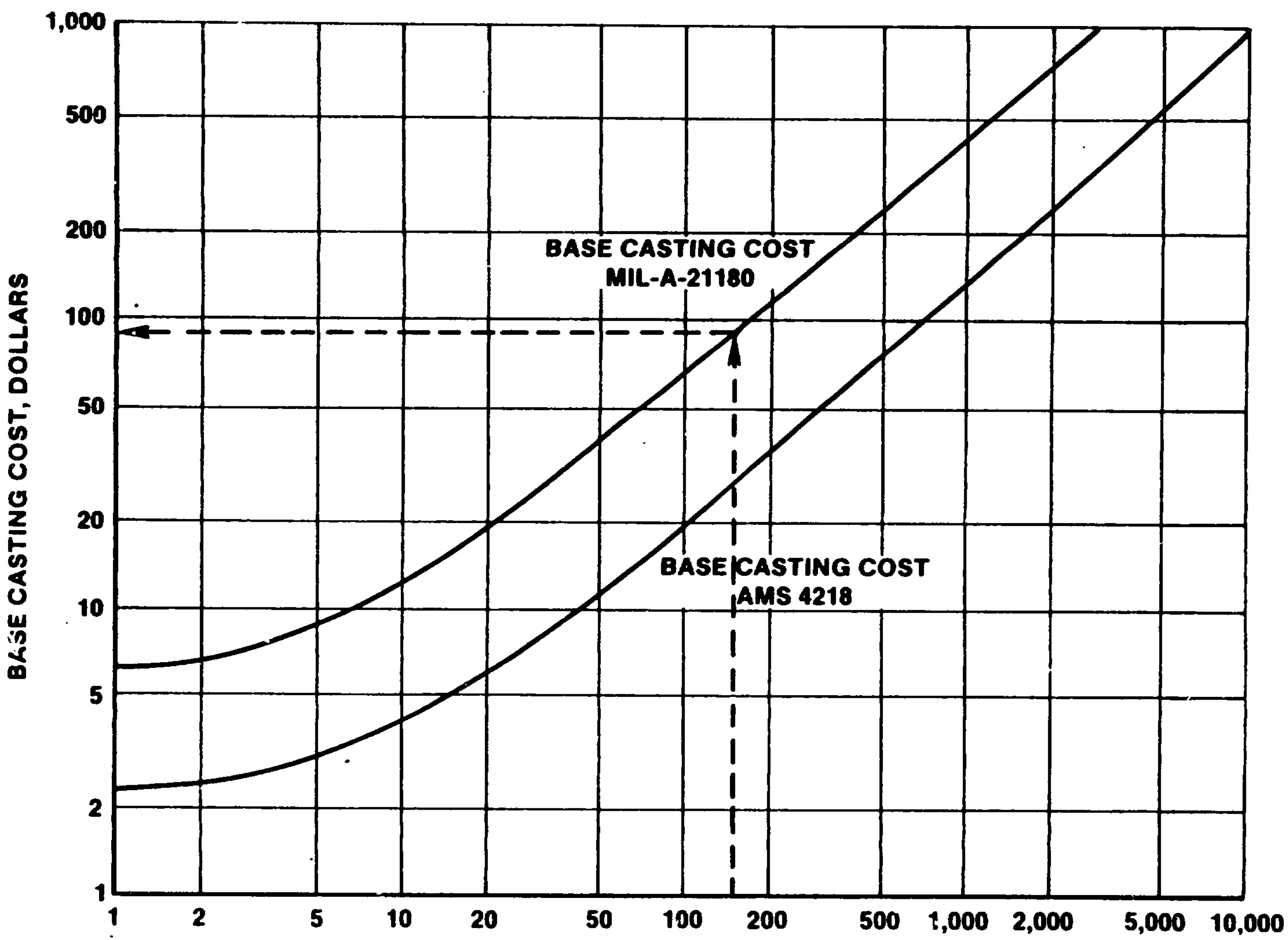
Where N is the number of clevises/part.

(1) 356-T6 Aluminum
(2) 17-4PH CRES

FIGURE 4.5-12. FORMAT USED IN EXAMPLE

CED-MC-7

356-T6/A356-T6 ALUMINUM INVESTMENT CASTING COST-ESTIMATING DATA



NOTE: ALUMINUM INVESTMENT CASTINGS OVER 1,730 CU.IN. BOX VOLUME TO BE APPROVED BY ENGINEERING VALUE, PRODUCIBILITY OR EQUIVALENT.

BOX VOLUME, CUBIC INCHES

CED-C-3

FIGURE 4.5-13. FORMAT USED IN EXAMPLE

DICE FACTORS FOR ALUMINUM INVESTMENT CASTINGS COST ESTIMATING DATA

NOTE: DICE FACTOR EQUAL TO ONE PLUS SUM OF ALL APPLICABLE DICE FACTOR INCREMENTS IN TABLE. RESULTING DICE FACTOR USED TO MODIFY BASE CASTING COST.

DESIGN FEATURE	DICE FACTOR INCREMENT
CASTING CLASSIFICATION	
Class II	—
Class I	$\boxed{0.10}$
X-RAY GRADE	
D	—
D with C Areas	—
C	—
C with B Areas	0.10
B	0.50
TOLERANCE — LENGTH/WIDTH	
±0.005"/in. ±0.010" min	—
±0.004"/in. ±0.010" min	0.20
±0.003"/in. ±0.010" min	0.50
TOLERANCE-THICKNESS	
±0.010	—
±0.008	0.10
±0.005	0.20
SURFACE FINISH	
C12	—
C9	Machine
C6	Machine
FILLET RADII	
R = Wall Thickness	—
R = 1/2 Wall Thickness	0.05
LOCAL THICK AREAS	
Under 0.25" Thick	—
0.25" to 0.50"	0.10
0.50" to 1.0"	0.25
1.0" to 2.0"	0.50
Over 2.0"	1.00
THROUGH HOLES	
None	—
Length/Dia. < 4	0.10
Length/Dia. - 4-8**	0.20
BLIND HOLES	
None	—
Length/Dia. < 4	0.20
Length/Dia. - 4-8**	0.40
CORES (SOLUBLE WAX)	
None	—
1-2 Cores	0.10
3-6 Cores	0.30
SLENDERNESS (RATIO L/W OR T)	
L/W or L/T < 6	—
L/W or L/T 6-12	0.10
L/W or L/T > 12	0.25

**Consult Value or Producibility Engineer

CED-DICE-C-2

FIGURE 4.5-14. FORMAT USED IN EXAMPLE

EFFECT OF BUY QUANTITY ON CASTING COST
COST-DRIVER EFFECT
ALL MATERIALS AND CASTING PROCESSES

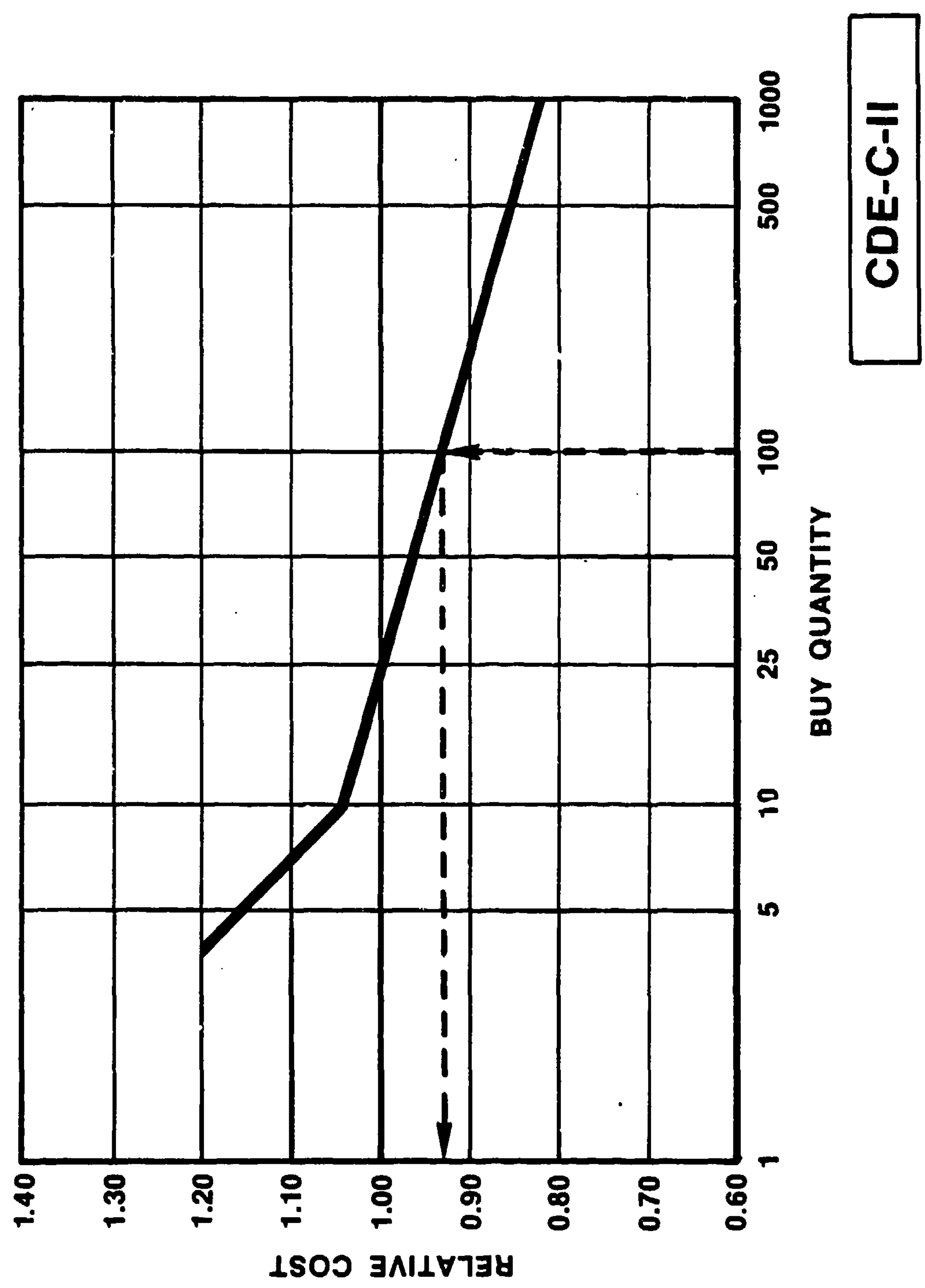


FIGURE 4.5-15. FORMAT USED IN EXAMPLE

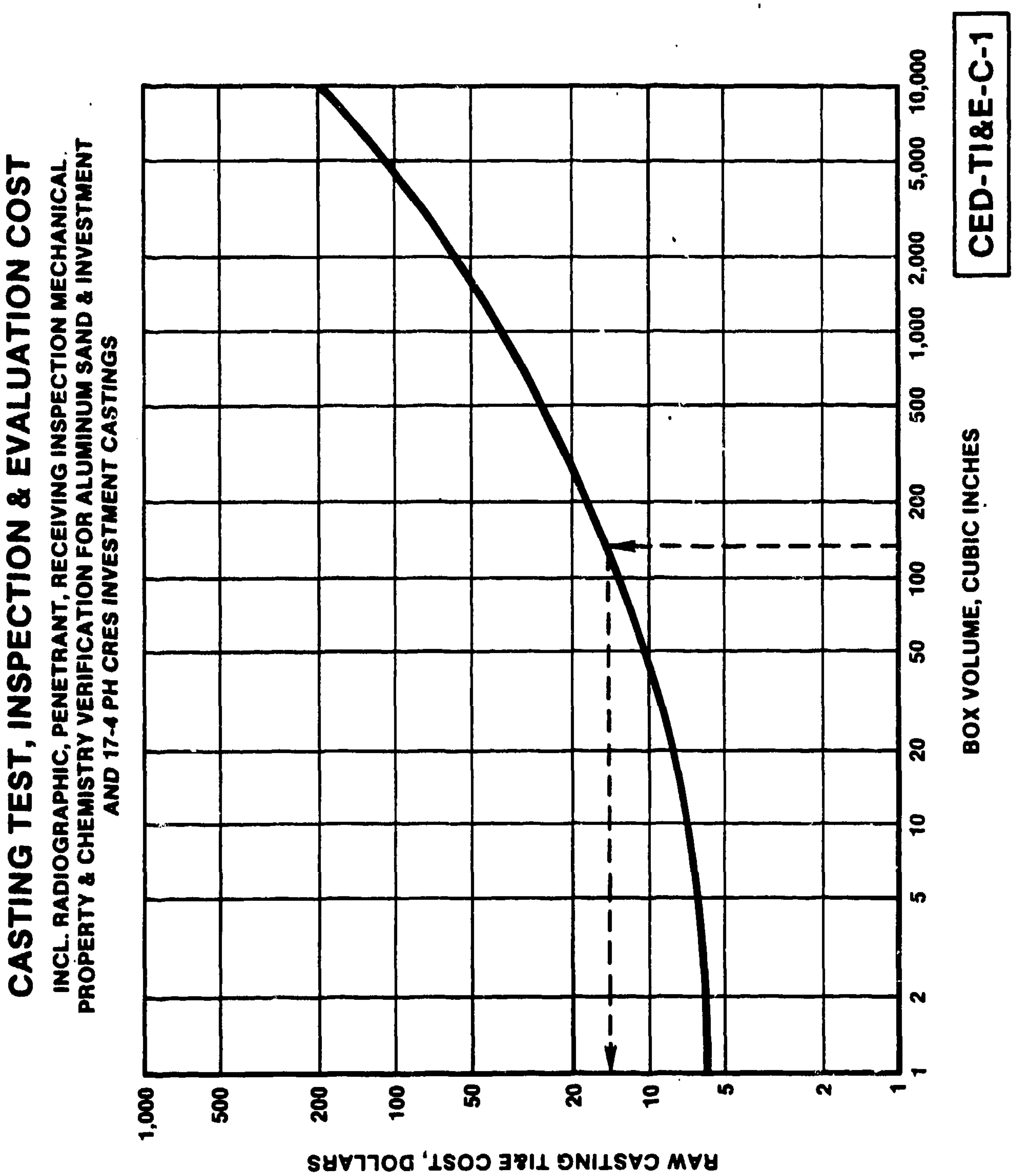


FIGURE 4.5-16. FORMAT USED IN EXAMPLE

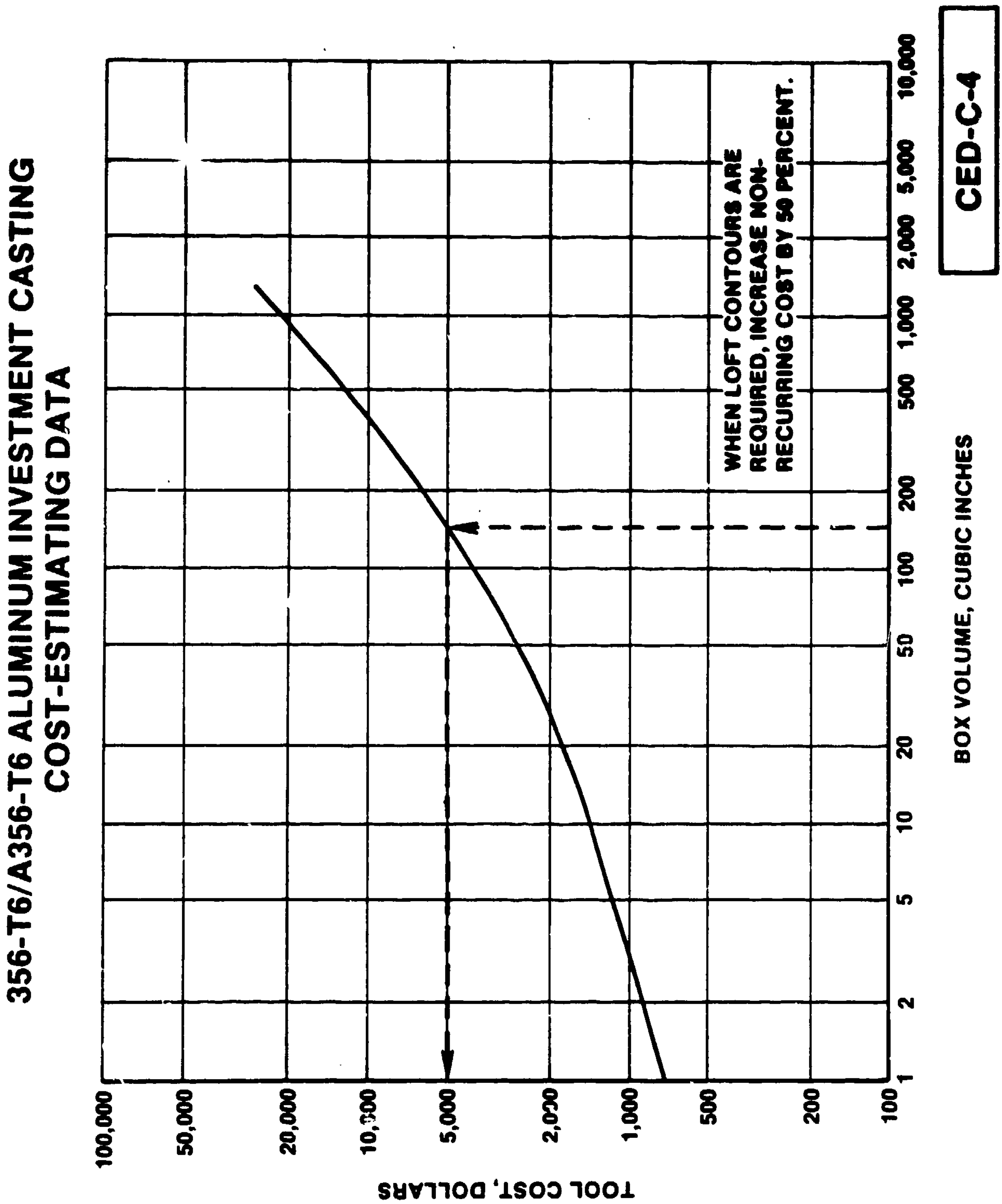
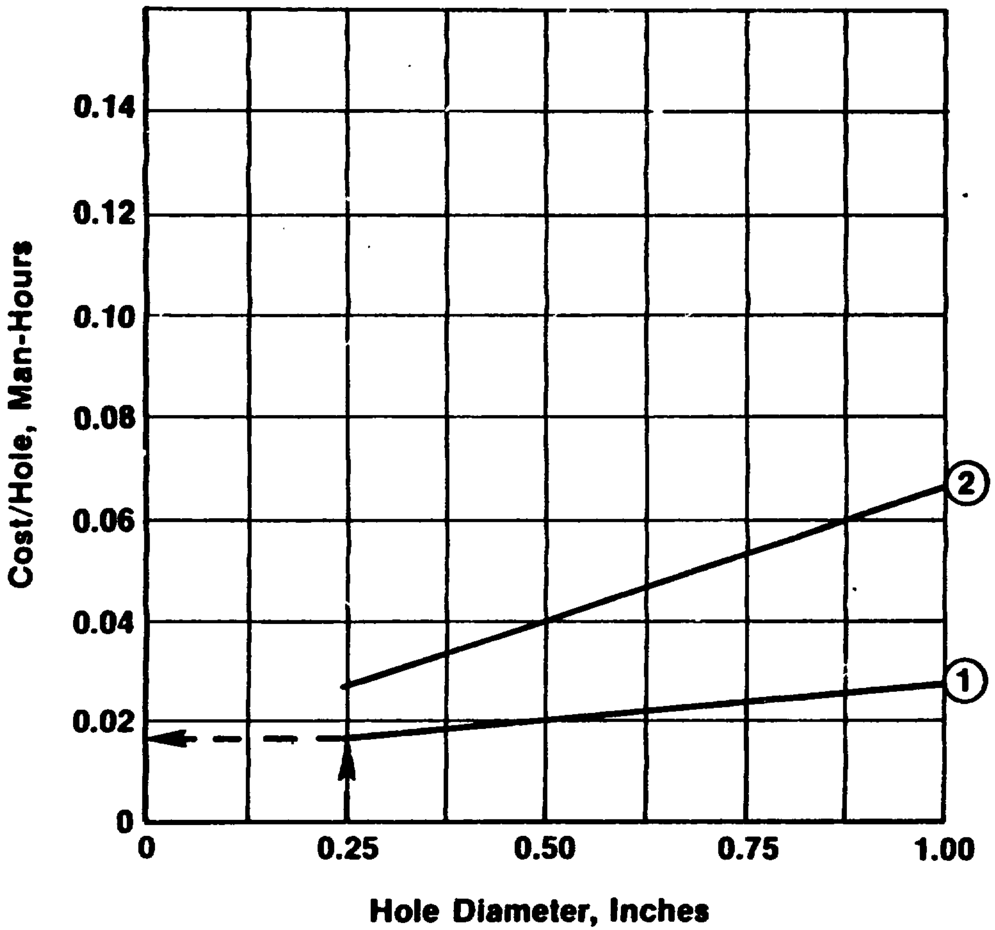


FIGURE 4.5-17. FORMAT USED IN EXAMPLE

MACHINING OF CASTINGS

DRILL HOLES



Nonrecurring Tool Cost

NRTC = (32 + 2N) Man-Hours

Where N is the number of holes in the pattern.

1 356-T6 Aluminum
2 17-4 PH CRES

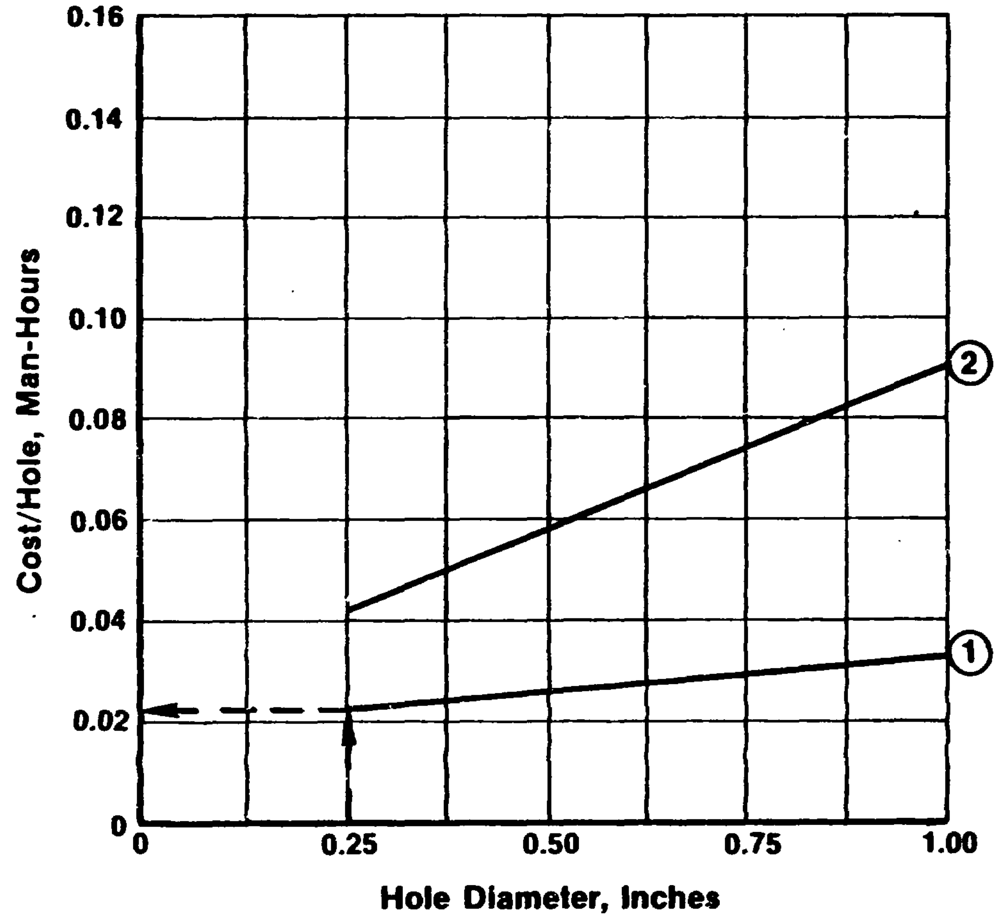
Cost/Part = (Cost/Hole • N) Man-Hours

Cost data is valid for hole depths up to twice the hole diameter.

CED-MC-1

FIGURE 4.5-18. FORMAT USED IN EXAMPLE

MACHINING OF CASTINGS
DRILL AND REAM HOLES



Nonrecurring Tool Cost

NRTC = (32 + 2N) Man-Hours

Where N is the number of holes in the pattern.

(1) 356-T6 Aluminum

(2) 17-4 PH CRES

Cost/Part = (Cost/Hole • N) Man-Hours

Cost data is valid for hole depths up to twice the hole diameter.

CED-MC-3

FIGURE 4.5-19. FORMAT USED IN EXAMPLE

TABLE 4.5-1

FACTORS TO CONVERT THE MC/DG 200TH UNIT COST TO THE CUMULATIVE AVERAGE COST FOR THE DESIGN QUANTITY AND LEARNING CURVE INVOLVED

DESIGN QUANTITY	LEARNING CURVE-%						
	95	90	85	80	75	70	65
1	1.48	2.25	3.48	5.50	9.00	15.00	27.00
10	1.33	1.79	2.47	3.48	5.04	7.53	11.67
25	1.25	1.59	2.05	2.71	3.68	5.13	7.43
50	1.19	1.44	1.79	2.22	2.85	3.76	5.14
100	1.13	1.30	1.52	1.80	2.18	2.73	3.51
200	1.08	1.17	1.30	1.45	1.66	1.95	2.36
350	1.04	1.08	1.14	1.22	1.33	1.48	1.70
500	1.01	1.02	1.05	1.09	1.15	1.24	1.38
750	0.98	0.96	0.96	0.96	0.97	1.01	1.09
1000	0.96	0.92	0.89	0.87	0.87	0.88	0.91

TABLE 4.5-2

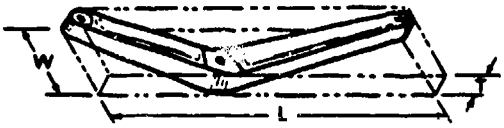
CASTING COST WORKSHEET

PREPARED BY: **DATE:**

PART TITLE ______________	**DESIGN QUANTITY** ______ **LOT QUANTITY** ______

MATERIAL	**SPECIFICATION**	**FOUNDRY PROCESS**
Aluminum	QQ-A-601 ______	
356 ______	MIL-A-21180 ______	Sand ______
A356 ______	AMS 4218 ______	Investment ______
Steel	AMS 5355 ______	
17-4 PH ______		

BOX VOLUME = W x L x T



ITEM	
RECURRING COST	
a) Base Cast Cost (Ref ______)	$ ______
b) DICE Factor (Ref ______)	______
c) Lot Quantity Factor (Ref ______)	______
d) Test Insp. & Eval. Cost (Ref ______)	$ ______
e) Inflation Factor	______
f) Recurring Cost (a x b x c + d)e	$ ______
NONRECURRING COST	
g) Base Nonrecurring Cost (Ref ______)	$ ______
h) N R DICE Factor (Ref ______)	______
i) Check Fixtures (Ref ______)	$ ______
j) Static Test Cost (Ref ______)	$ ______
e) Inflation Factor	______
k) Nonrecurring Cost = (g x h + i + j)e	$ ______
COST SUMMARY	
f) Recurring Cost/Part	$ ______
l) Machining Cost/Part	$ ______
m) Design Quantity	______
n) Program Recurring Cost (f + l)m	$ ______
k) Nonrecurring Cost	$ ______
o) Program Total Cost (n + k)	$ ______
p) Total Cost/Part (o ÷ m)	$ ______

TABLE 4.5-3

CASTING MACHINING COST WORKSHEET

MACHINING FEATURE	FORMAT	RECURRING COST	NONRECURRING COST
Holes - No. ____ Size ____ Drill Drill & Spotface Drill & Ream Cost Per Part		MH	MH
Flange Facing Mean Diam ____ Width ____ Cost Per Part		MH	MH
Face Milling Area Milled ____ Sq. In. Cost Per Part		MH	MH
Face & Counterbore Hub Ctrbore Diam ____ No. ____ Cost Per Part		MH	MH
Clevis-Str. Mill/Drill/Ream No. ____ Size ____ Cost Per Part		MH	MH
Machining Cost (Unit 200) Per Part		MH	MH
Learning Curve Factor Labor Rate Machining Cost/Part* Nonrecurring Cost		____ $ ____ /HR $ ____	 $ ____ /HR $ ____

*Machining cost/part = U200 cost/part x LC factor x labor rate.

Des. Qty	LC Factor	Des. Qty	LC Factor
1	2.25	200	1.17
10	1.79	350	1.08
25	1.59	500	1.02
50	1.44	750	0.96
100	1.30	1000	0.92

90% Learning Curve Factor to Convert Unit 200 Format Cost to Cumulative Average Cost for Various Design Quantity.

4.5.3 Cast Parts Analyzed

Examples of cast parts analyzed to determine the manufacturing man-hours are shown in Figure 4.5-4. Designer-influenced cost elements (DICE) for castings can significantly increase manufacturing cost and therefore examples of DICE are shown in Figures 4.5-5 and 4.5-6.

It was considered convenient to classify castings into the groupings shown in Figure 4.5-4, i.e., simple, average and complex. These classifications are defined below:

Simple Castings

Type "A"

All tolerances, thicknesses, X-ray grade, cast surface finish $\geq$ than recommended. Simple shapes, uniform sections, no coring required.

Type "B"

May require one or two dimensions held tighter than recommended, or small local grade "B" X-ray requirements, or small local thin wall at one place. Regular shape casting with moderate wall thickness changes.

Average Castings

Type "C"

This casting may require separate cores, plus three or four dimensions are required tighter than recommended. Multi-piece or split mold. Several pockets or protrusions. Less than three cored holes.

Type "D"

Requires approximately three complex cores or some soluble coring. Varying wall thicknesses. Several thin or thick webs. Small local surface requiring C-12 or C-6 cast surface finish. Local grade "B" X-ray requirements.

Complex Castings

Type "E"

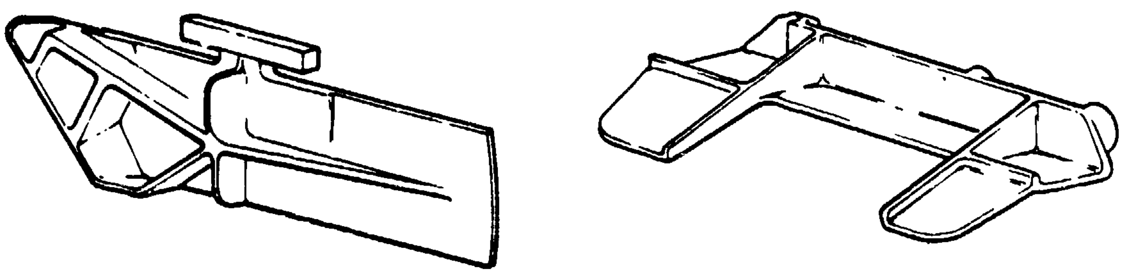
Several complex cores required with marginal L/D ratios. Thin and heavy sections up to seven or eight dimensions that require tolerancing tighter than standard. Up to 15 percent of casting requires grade "B" X-ray level.

Type "F"

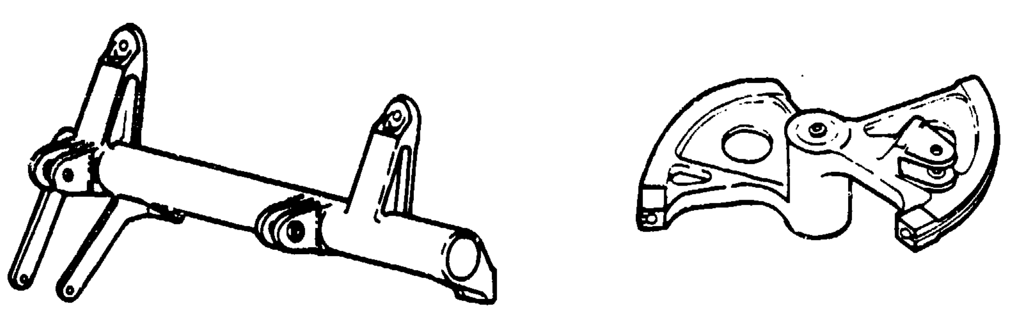
25 percent of casting surface requires grade "B" X-ray level. One or more surfaces require C-12 or C-6 cast surface roughness. Multi-piece large tooling elements. Many thin or heavy webs. Many tight tolerances on location and thickness dimensions. Complex soluble coring required. Welded core support (chaplets) plugs required.

SAMPLE PARTS USED TO DERIVE CASTING COST DATA FOR MC/DG

SIMPLE CASTINGS



AVERAGE COMPLEXITY CASTINGS



HIGH COMPLEXITY CASTING

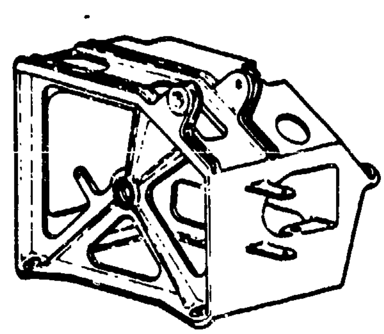


FIGURE 4.5-20

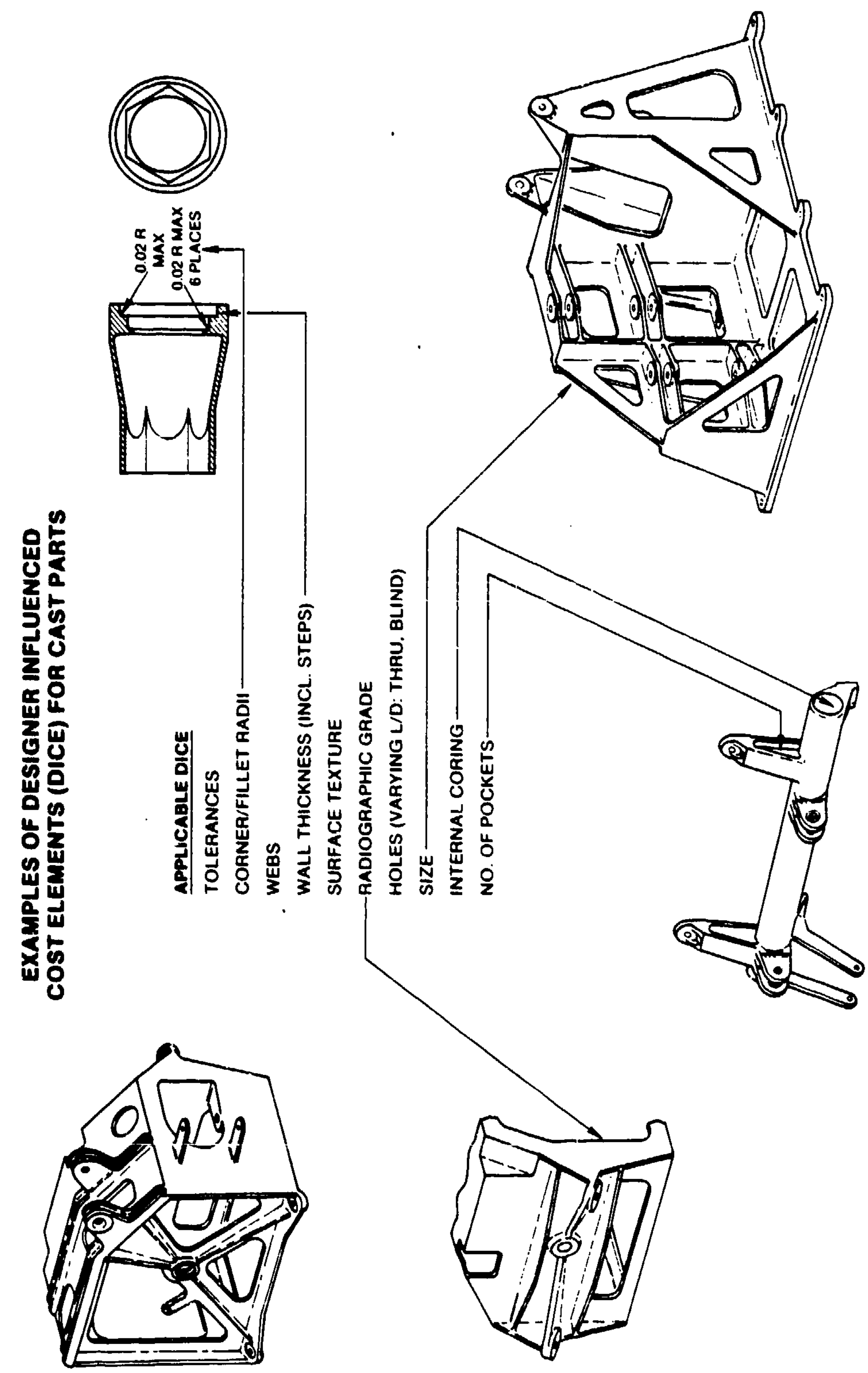


FIGURE 4.5-21. EXAMPLES OF DICE FOR CASTINGS

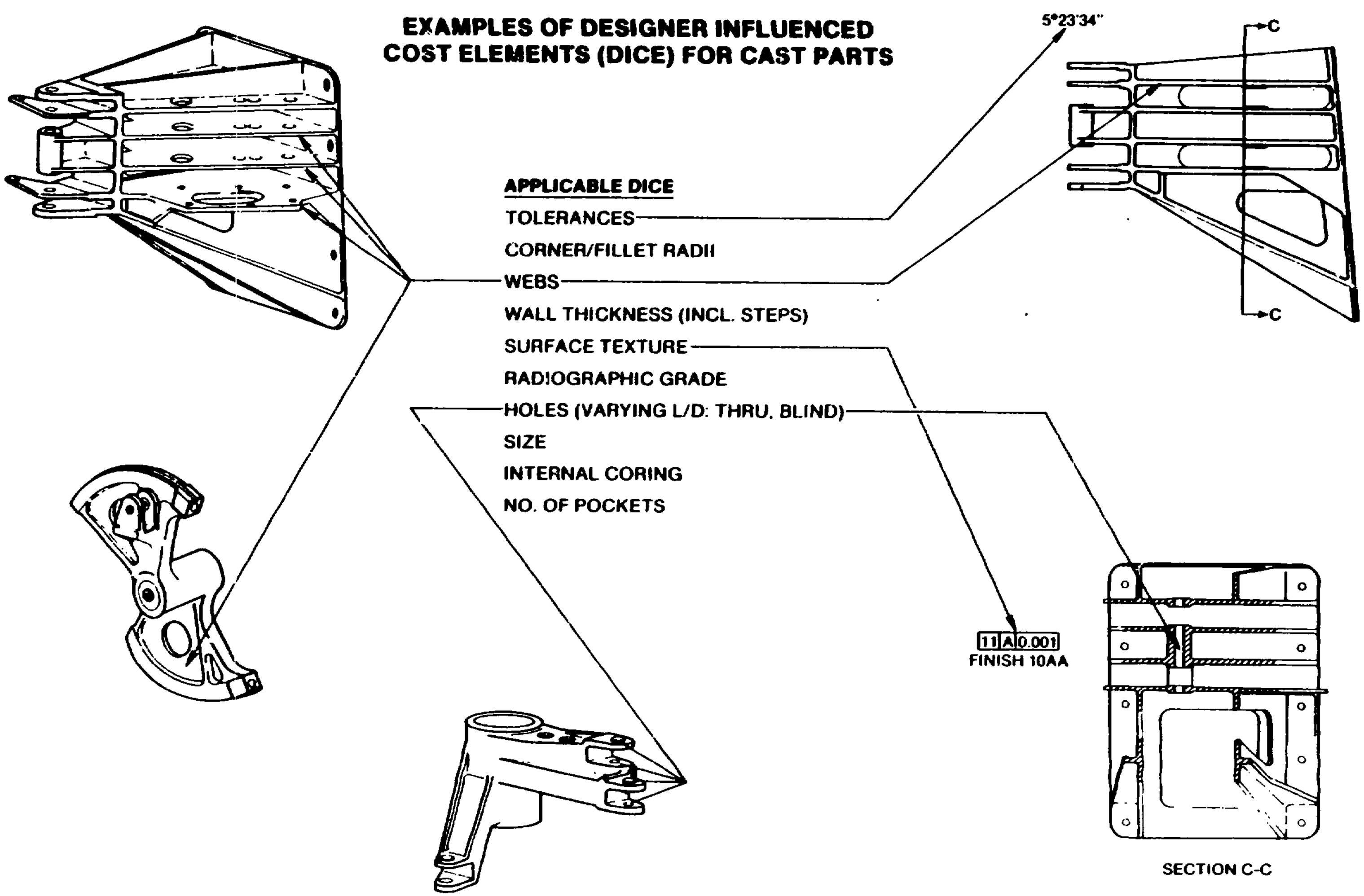


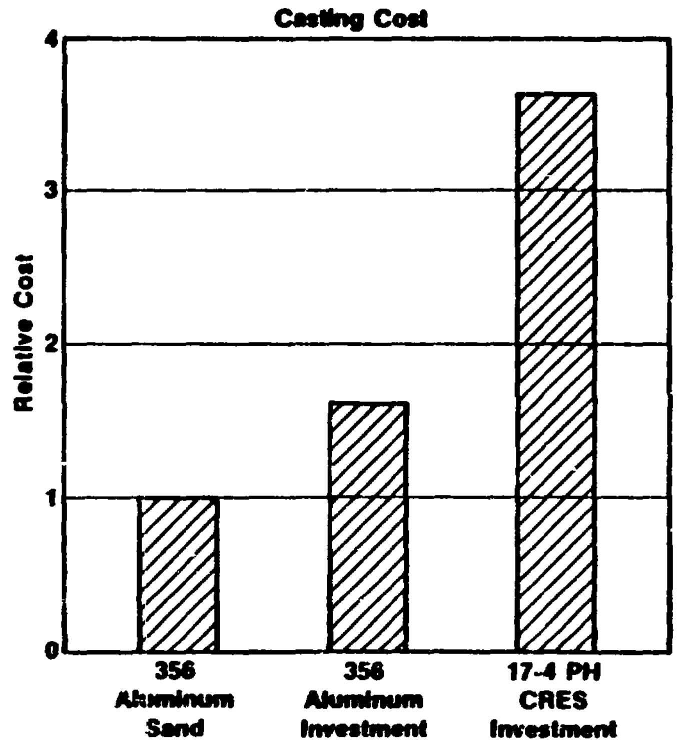
FIGURE 4.5-22. EXAMPLES OF DICE FOR CASTINGS

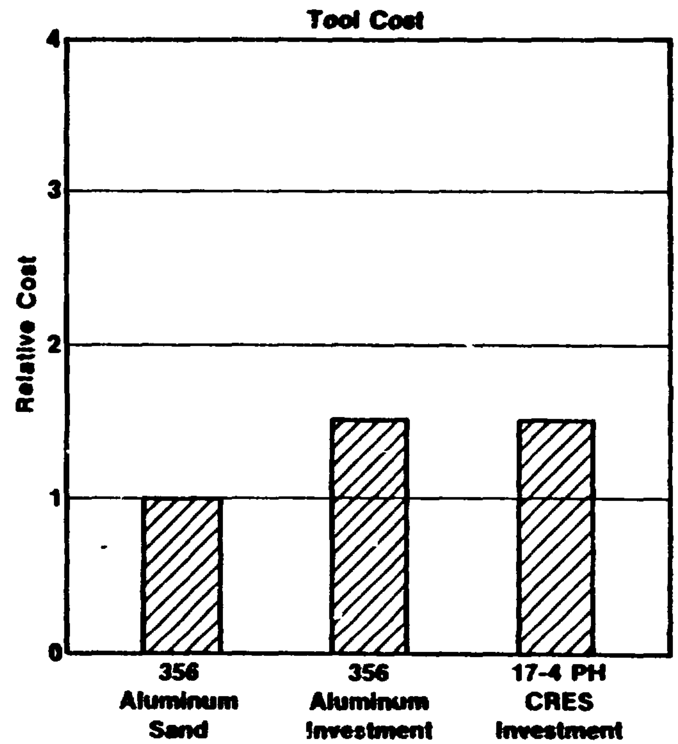
4.5.4 Data for Castings

The data on the following pages provide designer guidance to lowest cost and also enable cost trade-off studies to be conducted in accordance with the formats shown on the selection aids (Figures 4.5-1 to 4.5-3). As castings require additional operations prior to assembly in an airframe or other applications, formats to include the cost of machining are also included in this section (Formats CDE-MC-1, CDE-MC-II, and CED-MC-1 to CED-MC-6).

COST IMPACT OF CASTING MATERIAL & FOUNDRY PROCESS

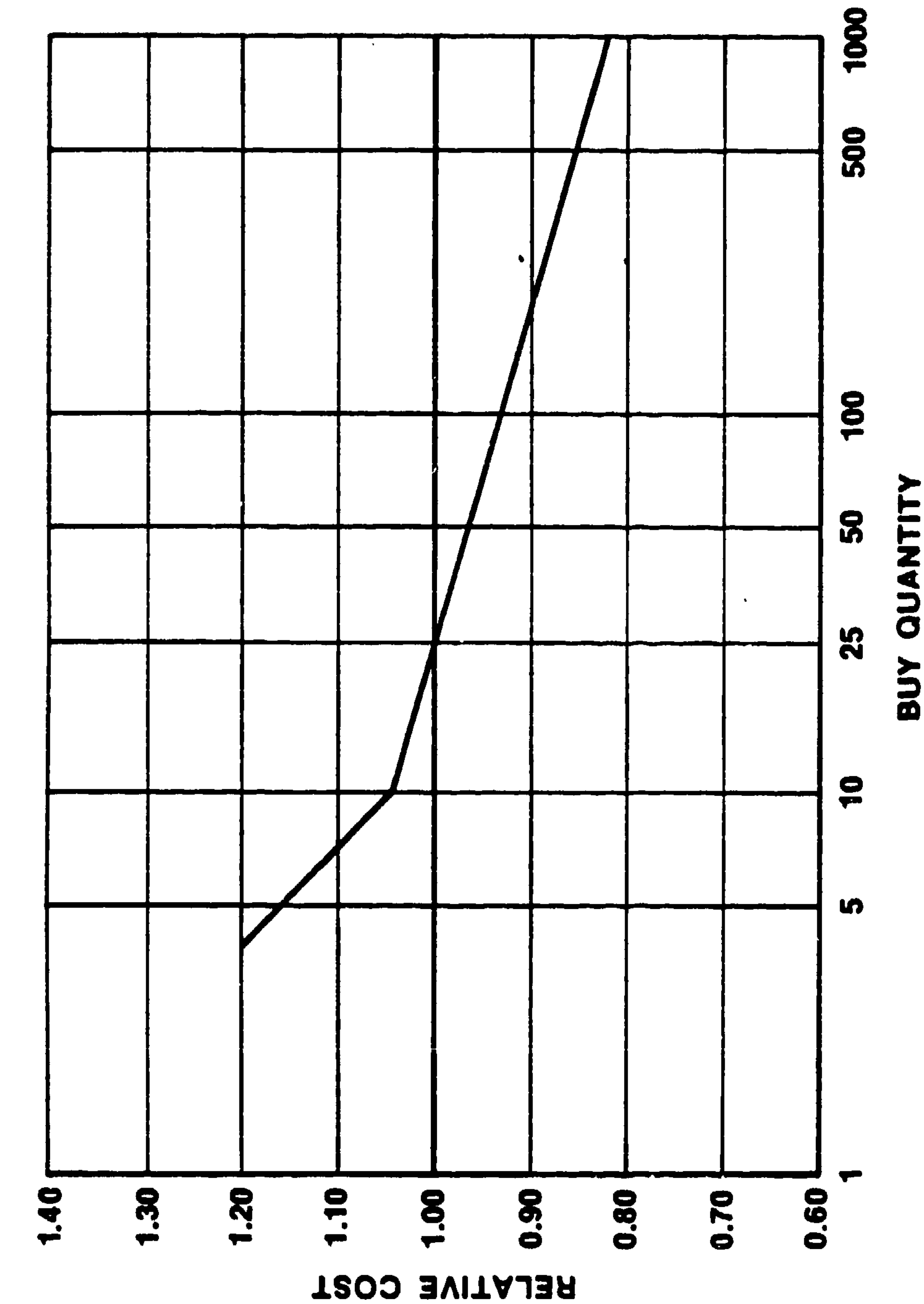
COST DRIVER EFFECT





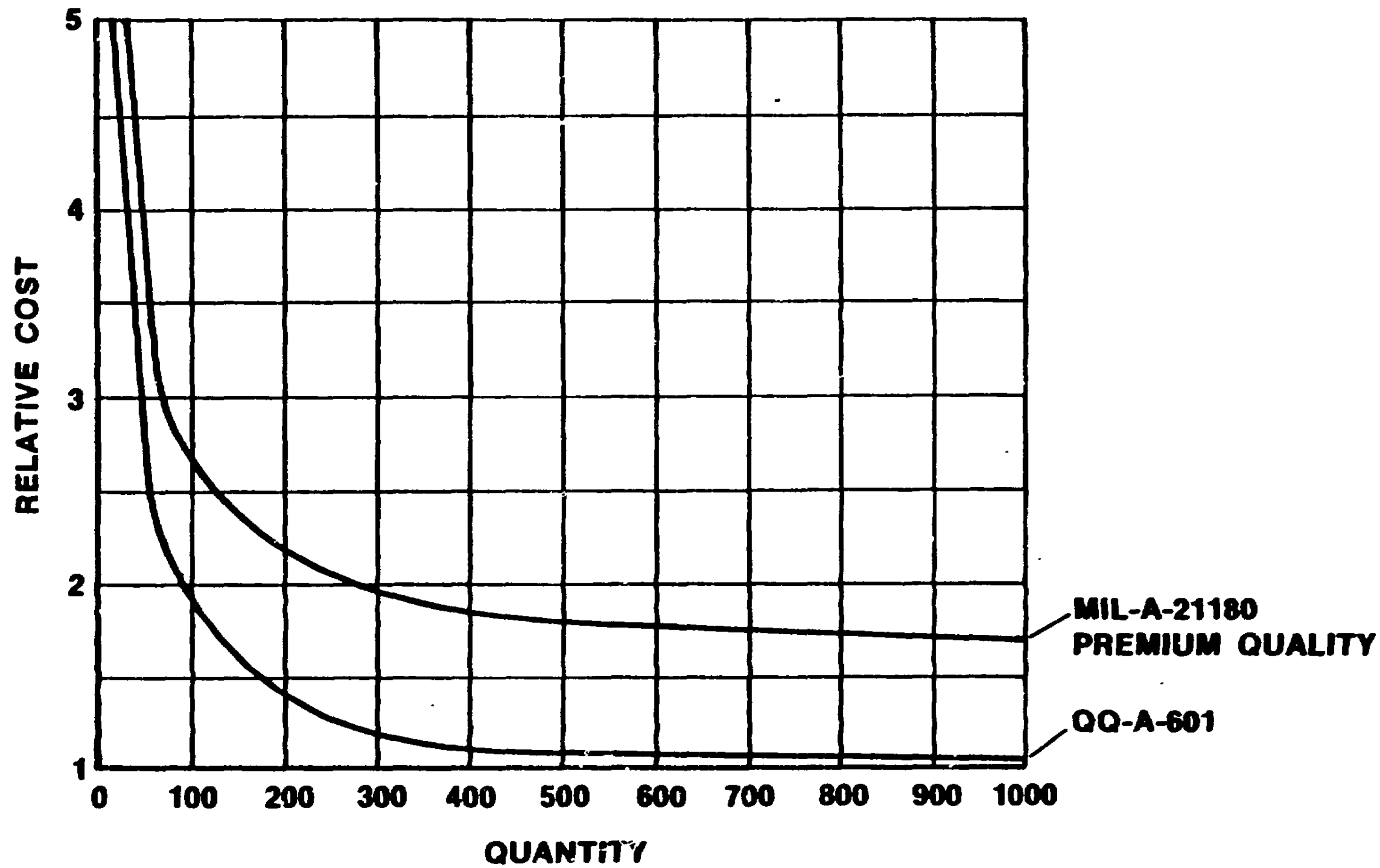
CDE-C-I

EFFECT OF BUY QUANTITY ON CASTING COST
COST-DRIVER EFFECT
ALL MATERIALS AND CASTING PROCESSES



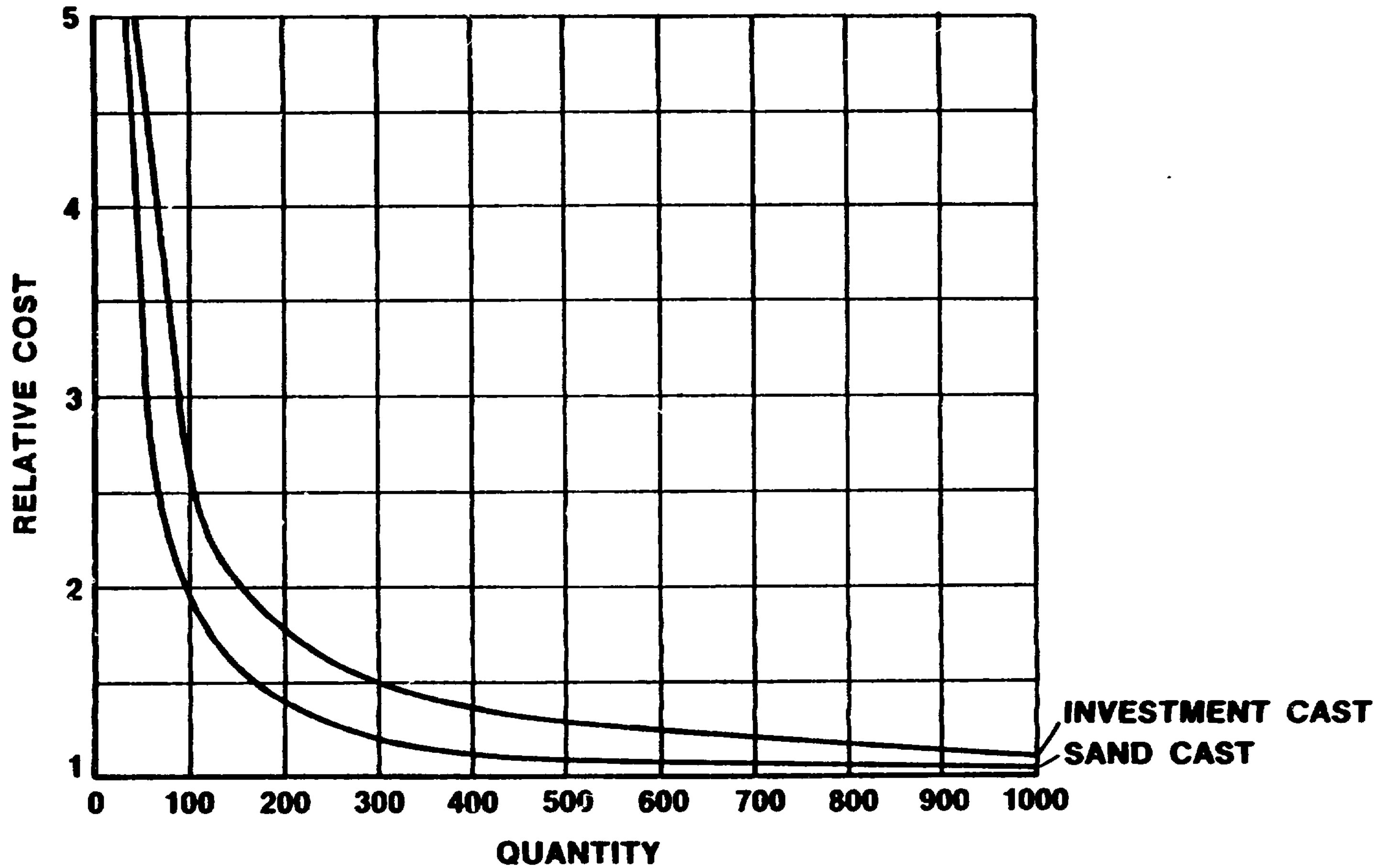
CDE-C-II

EFFECT OF "SPECIFICATION SELECTION" ON COST OF 356/A356 ALUMINUM SAND CASTINGS COST-DRIVER EFFECT



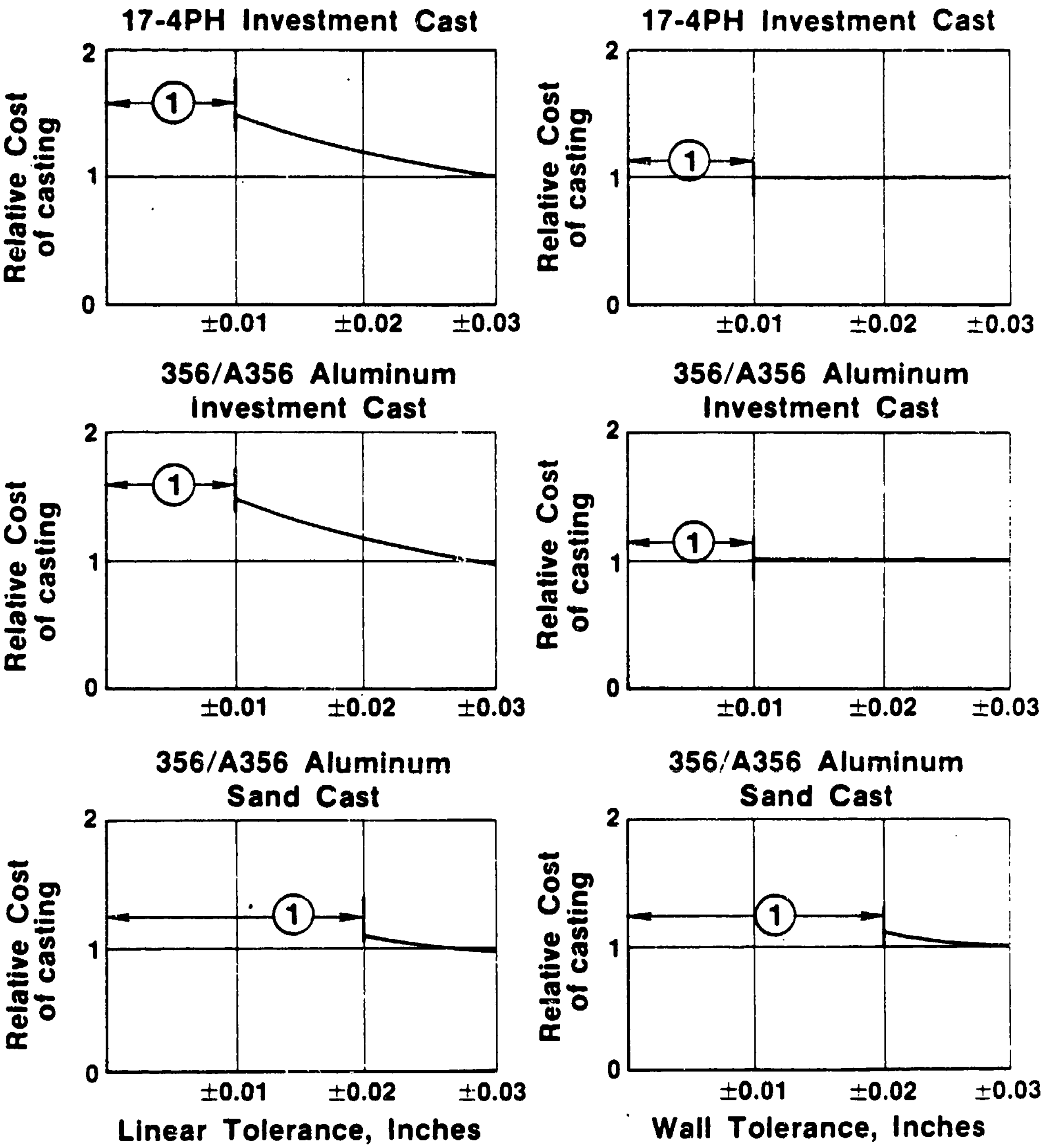
CDE-C-III

EFFECT OF "FOUNDRY PROCESS" ON COST OF 356/A356 ALUMINUM CASTINGS COST-DRIVER EFFECT



CDE-C-IV

CASTING TOLERANCES
COST-DRIVER EFFECT



① Impractical
② Based on a 7-Inch Linear Dimension

CDE-DICE-C-I

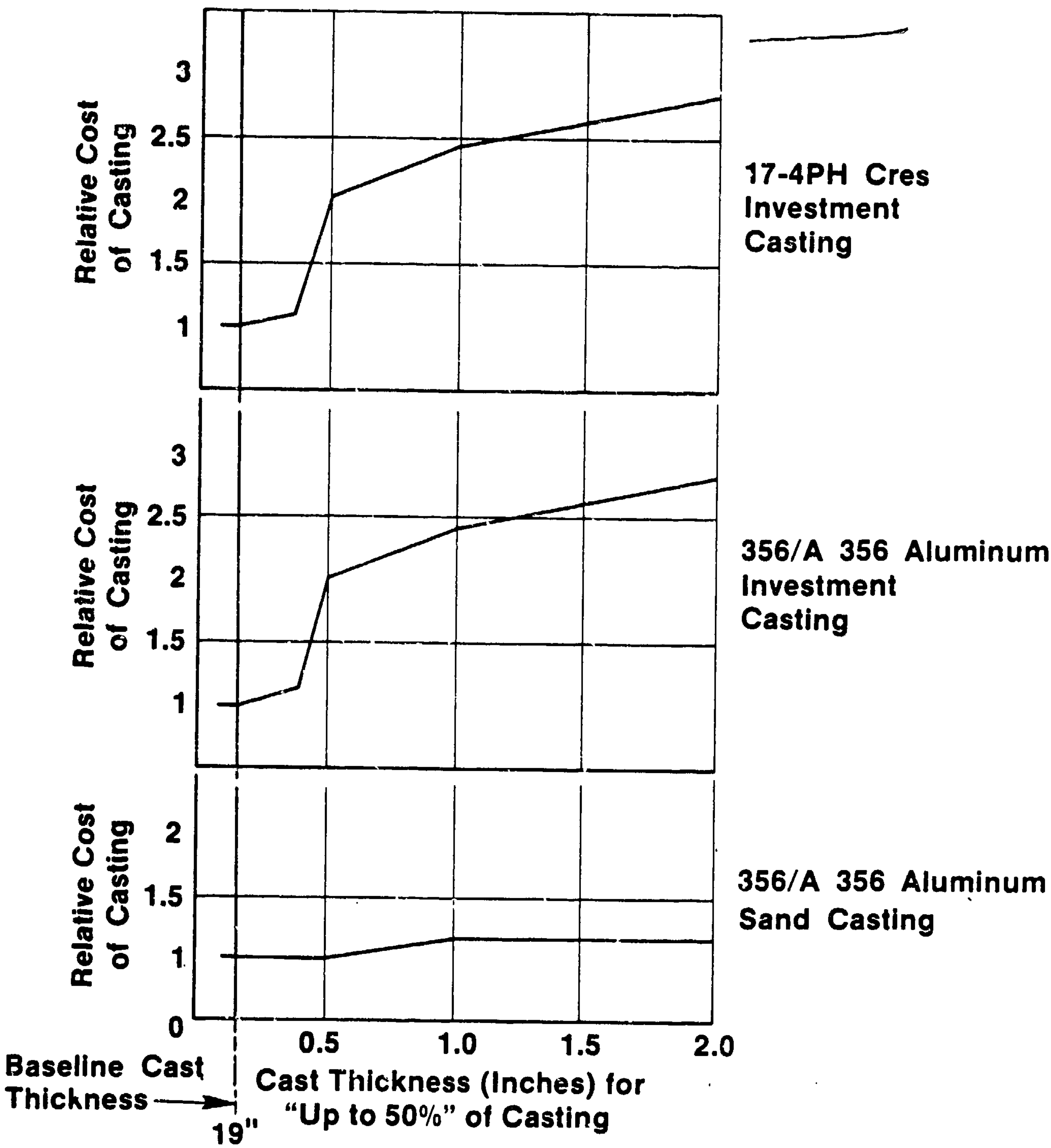
X-RAY GRADE REQUIREMENT COST DRIVER EFFECT

CASTING MATERIAL & PROCESS	X—RAY GRADE	COST EFFECT
356/A356 ALUMINUM SAND CAST	D OR C D OR C WITH 10% B D OR C WITH 50% B B	BASE +15% +25% +50%
356/A356 ALUMINUM INVESTMENT CAST	D OR C D OR C WITH 10% B D OR C WITH 50% B B	BASE +10% +20% +50%
17-4PH CRES INVESTMENT CAST	D OR C D OR C WITH 10% B D OR C WITH 50% B B	BASE +20% +30% +60%

NOTE: X-Ray Grade A is an Impractical Requirement for General or Local Areas of Casting.

CDE-DICE-C-II

COST IMPACT OF CHANGE IN CAST THICKNESS
COST-DRIVER EFFECT



CDE-DICE-C-III

CAST SURFACE FINISH
COST-DRIVER EFFECT

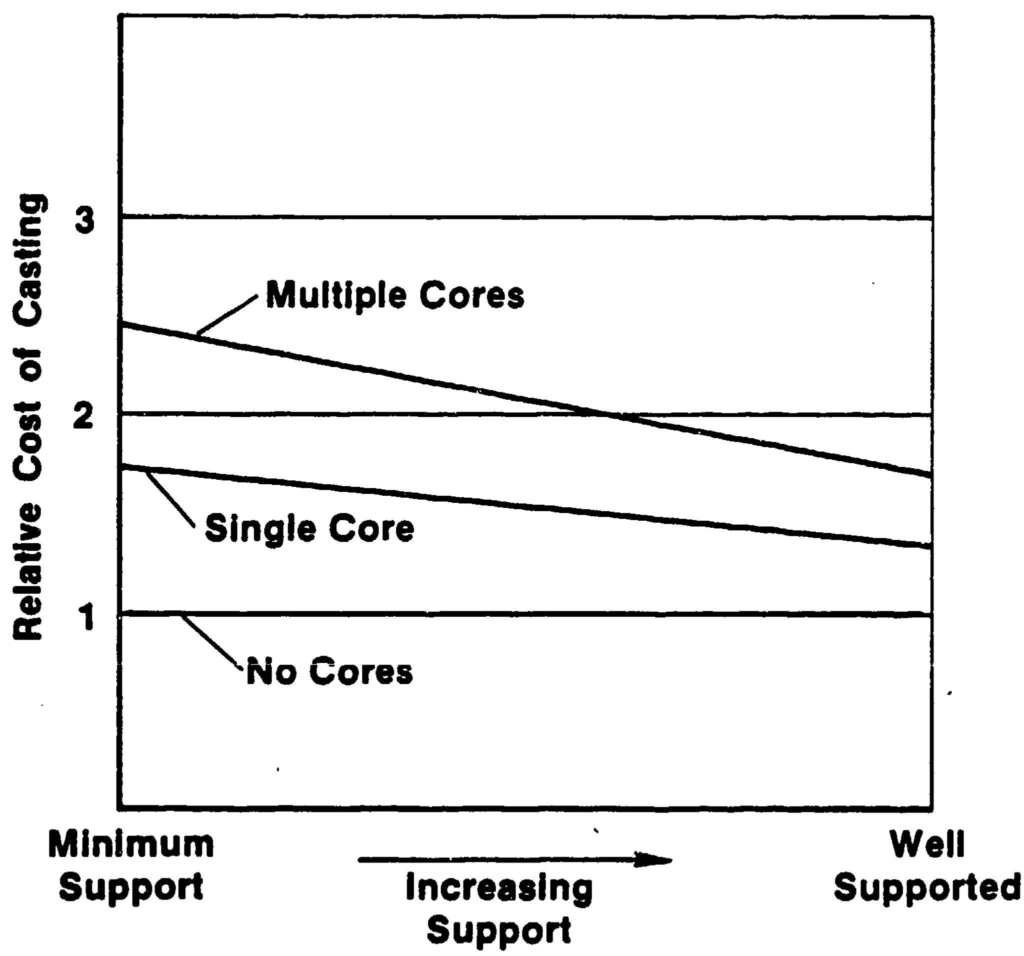
Casting Surface		Cost Effort			
Cast Surface Finish Designation	Equivalent Machine Finish - Micro Inches	356/A356 Aluminum Sand Casting		356/A356 Aluminum & 17-4 Cres Investment Casting	
		% of Surface		% of Surface	
		10%	50%	10%	50%
C-25	250	Base	Base	Base	Base
C-20	200	+10%	+20%	↕	↕
C-15	150	+10%	1	↕	↕
C-12	125	+10%	1	Base	Base
C-9	90	1	1	1	1
C-6	63	1	1	1	1

1 Impractical

CDE-DICE-C-IV

IMPACT OF CORES AND DEGREE OF CORE SUPPORT ON COST OF ALUMINUM SAND CASTINGS

COST-DRIVER EFFECT

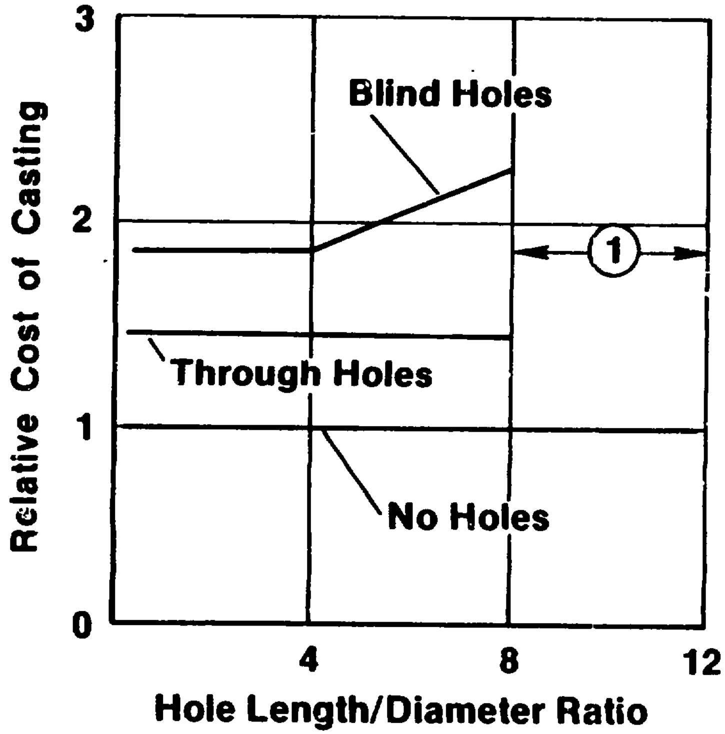


CDE-DICE-C-V

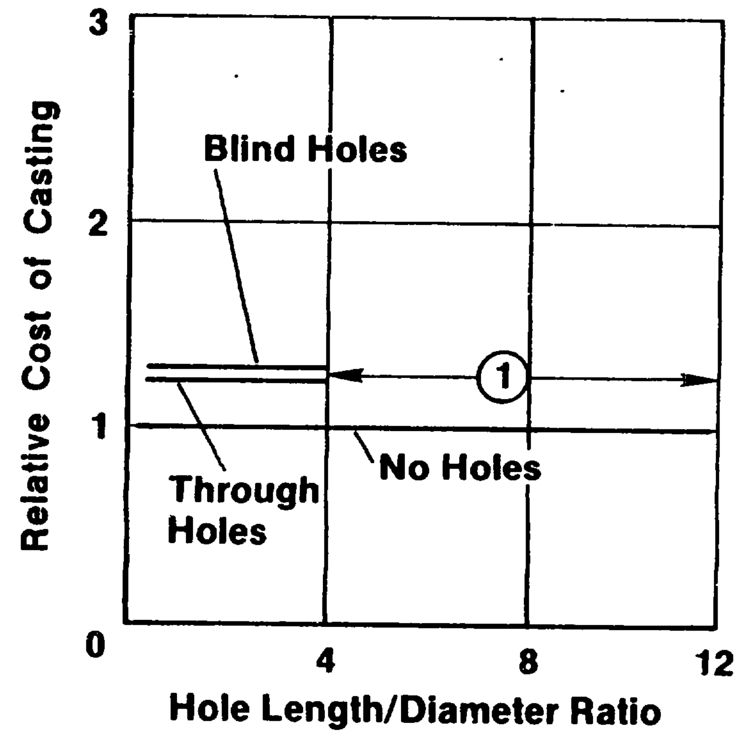
EFFECT OF THROUGH & BLIND HOLES ON THE COST OF CASTINGS

COST-DRIVER EFFECT

356/A356 Aluminum Sand Castings



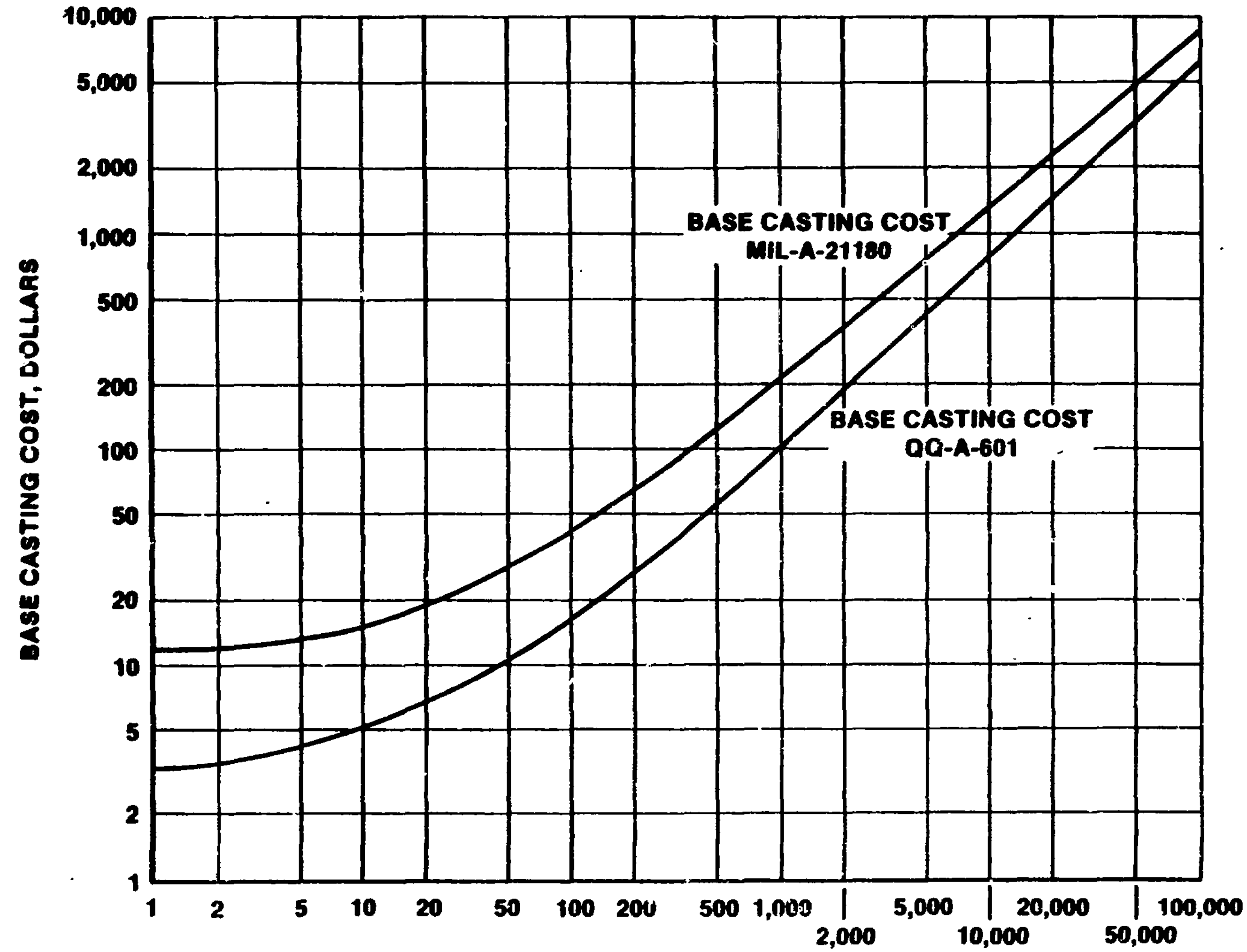
356/A356 Aluminum & 17-4 Cres Investment Castings



(1) Impractical

CDE-DICE-C-VI

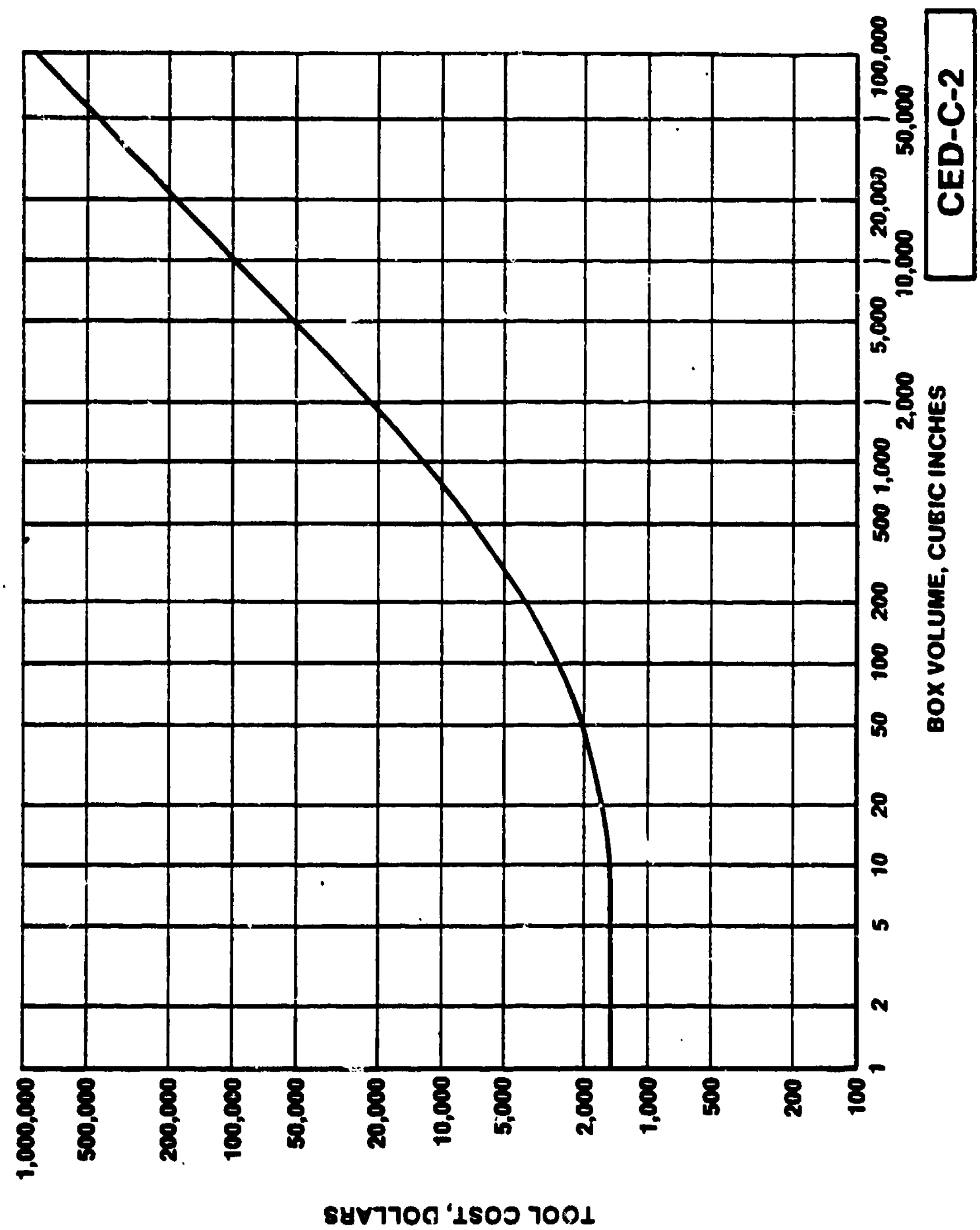
356-T6/A356-T6 ALUMINUM SAND CASTING COST-ESTIMATING DATA



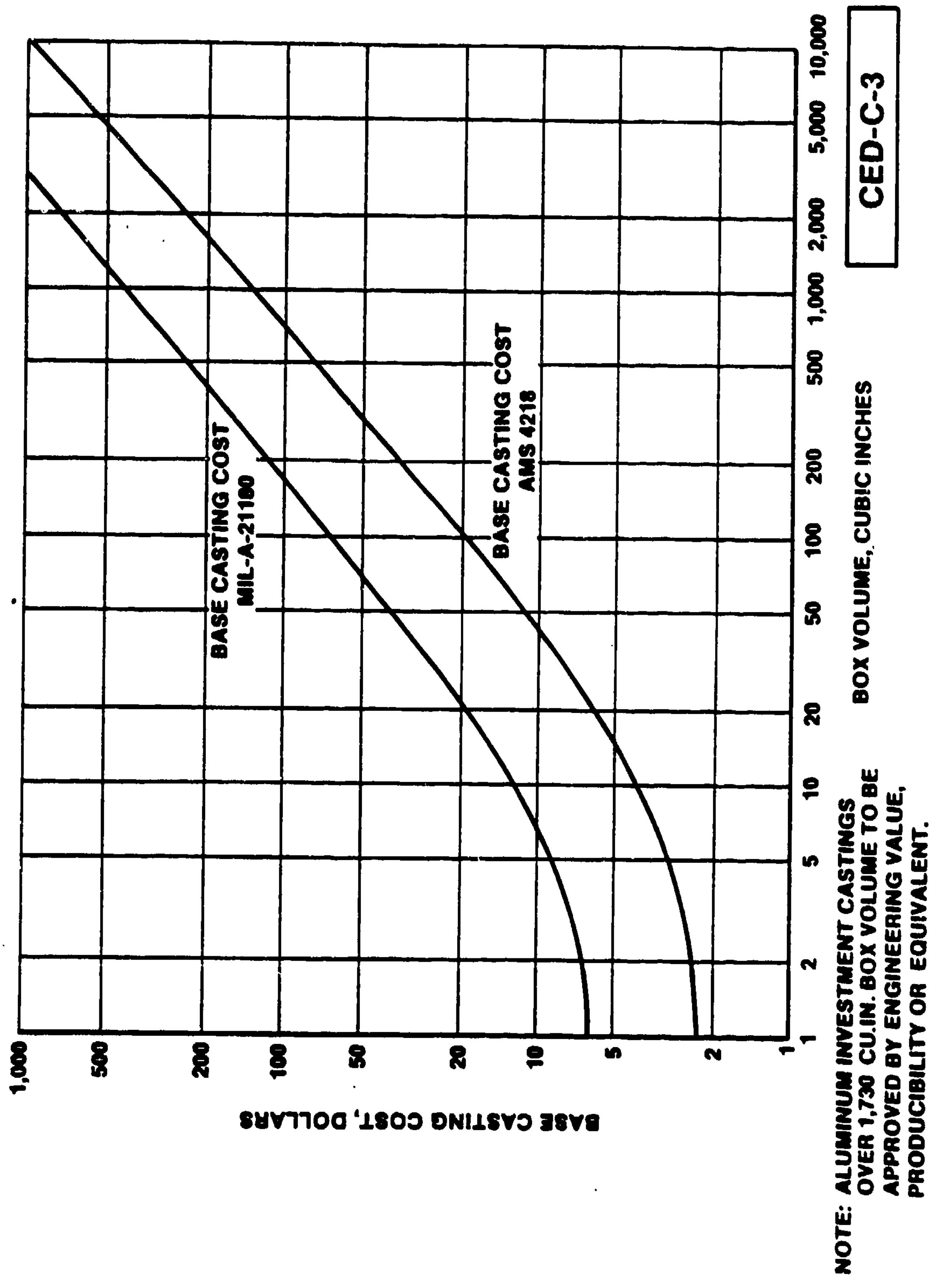
NOTE: SAND CASTINGS OVER 10,000 CU.IN. TO BE APPROVED BY ENGINEERING VALUE, PRODUCIBILITY OR EQUIVALENT.

CED-C-1

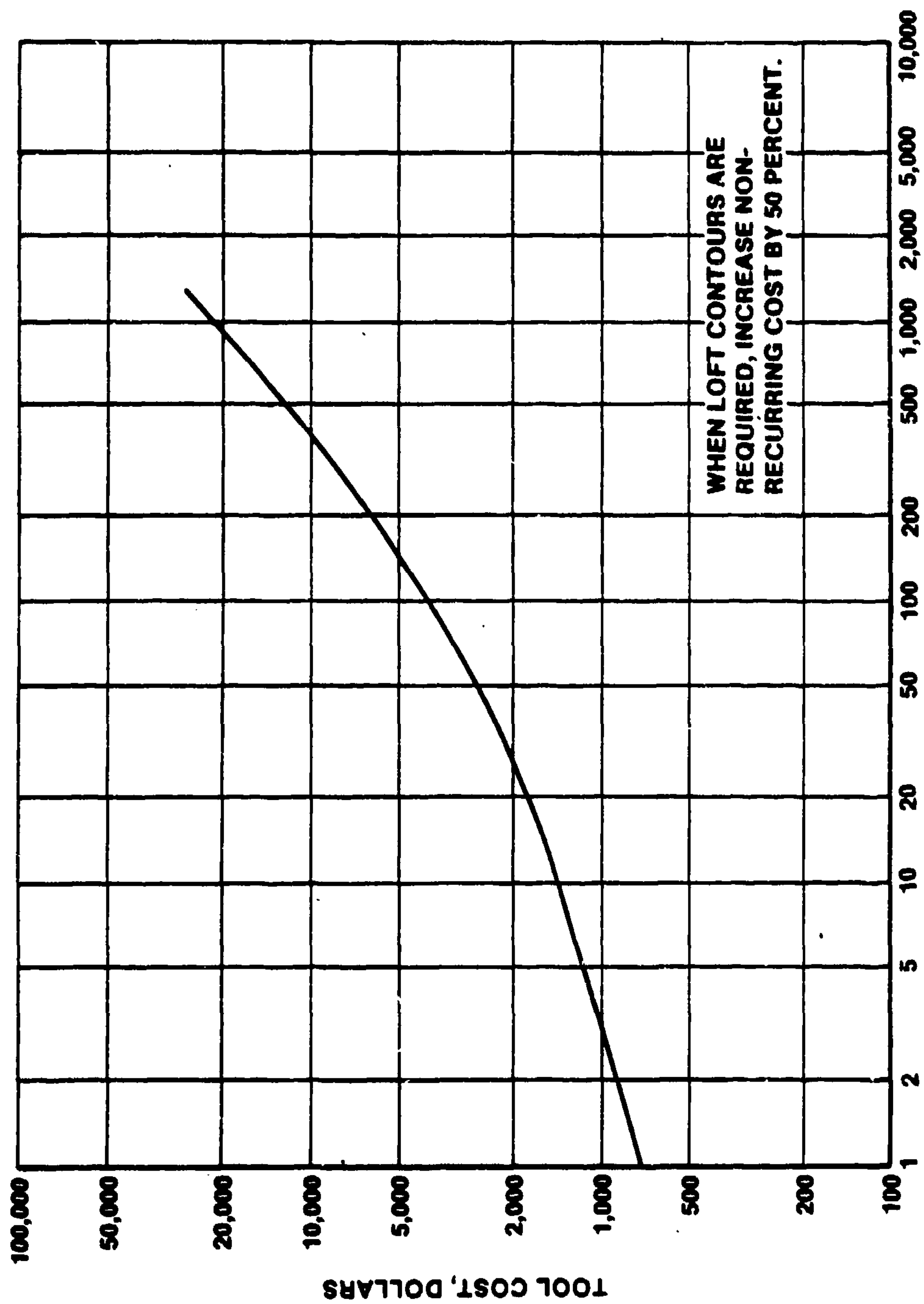
356-T6/A356-T6 ALUMINUM SAND CASTING
COST-ESTIMATING DATA



356-T6/A356-T6 ALUMINUM INVESTMENT CASTING COST-ESTIMATING DATA

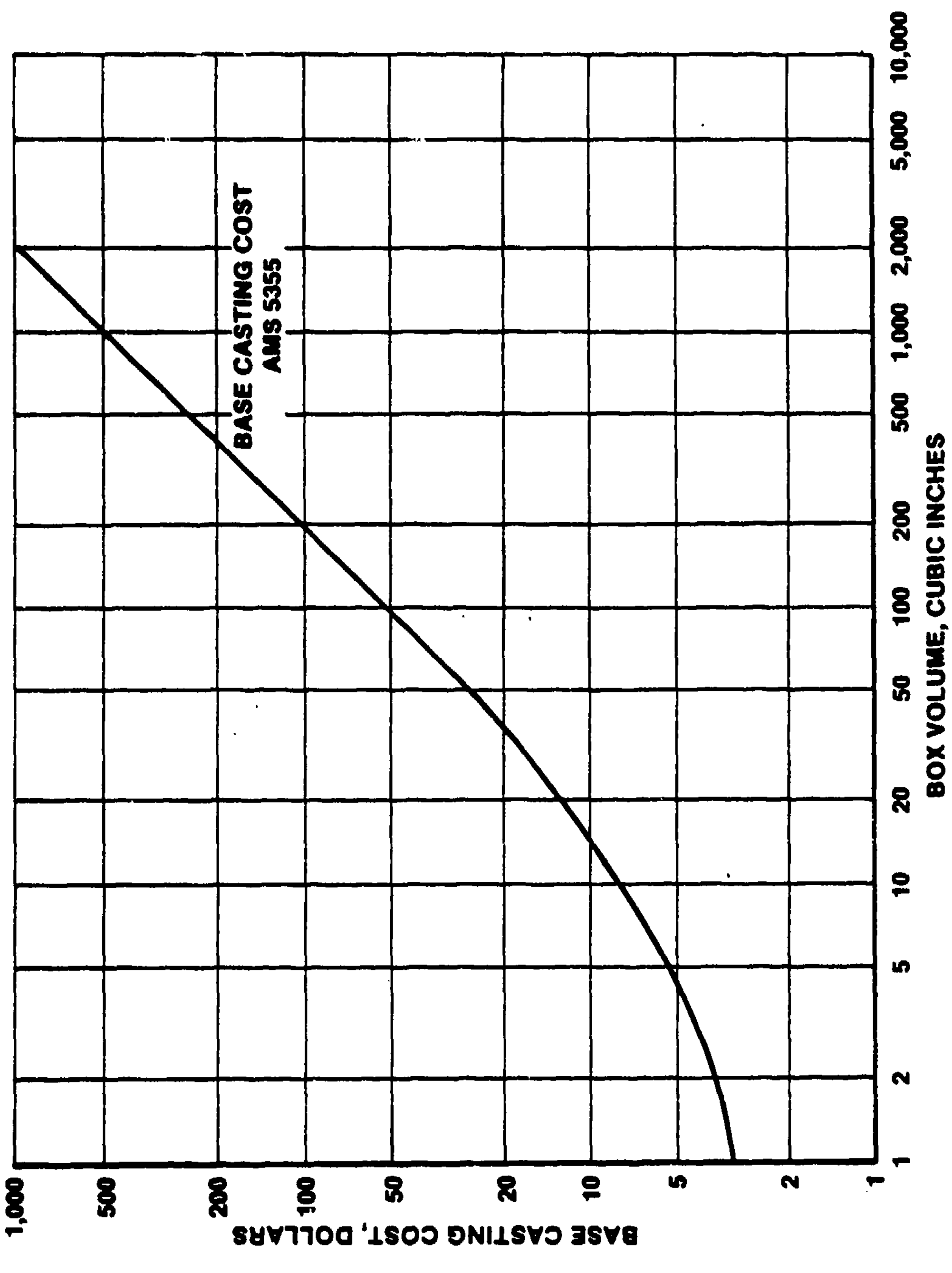


356-T6/A356-T6 ALUMINUM INVESTMENT CASTING
COST-ESTIMATING DATA



CED-C-4

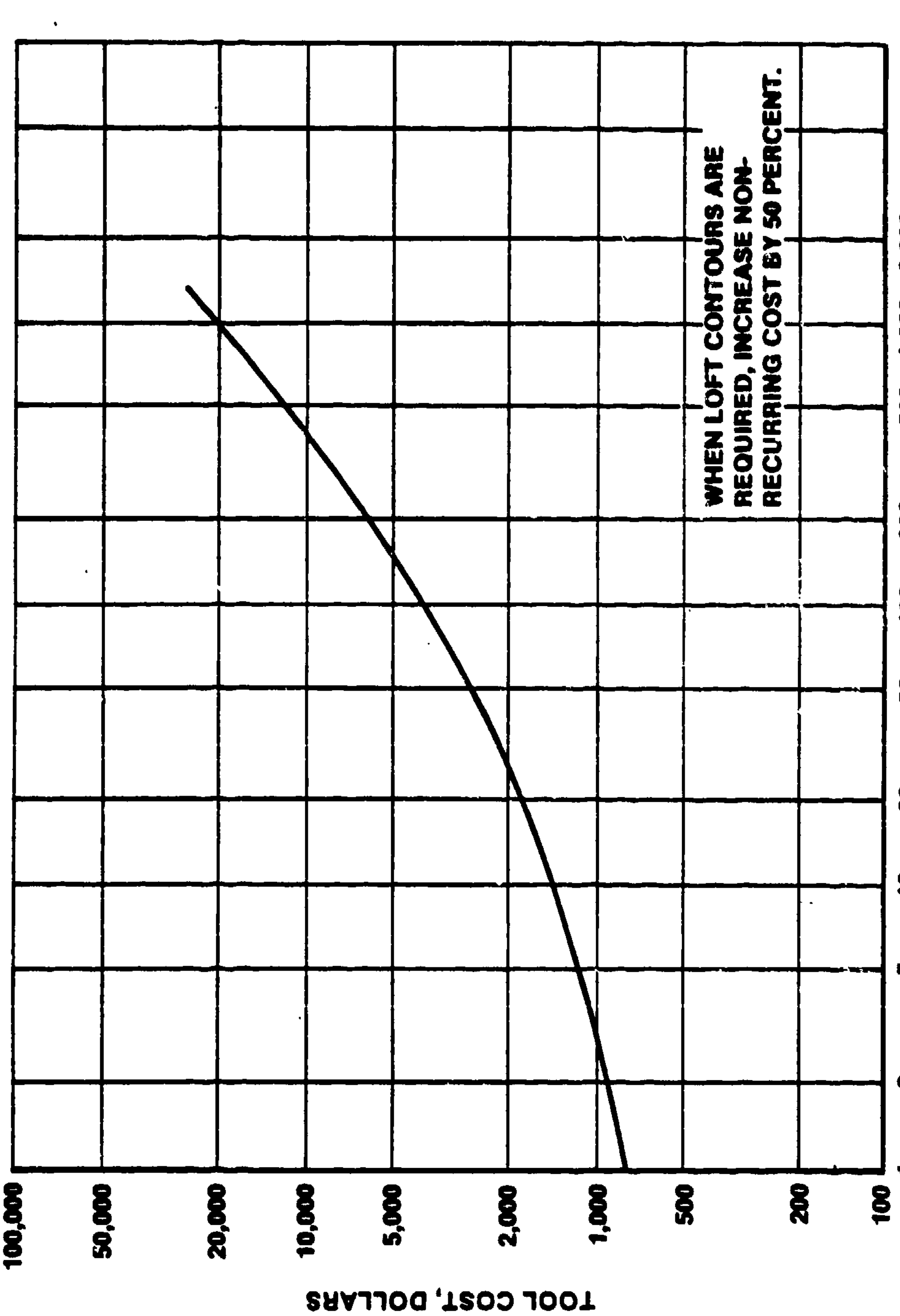
17-4 PH CRES INVESTMENT CASTING COST-ESTIMATING DATA



NOTE: STEEL INVESTMENT CASTINGS OVER 510 CU.IN. BOX VOLUME TO BE APPROVED BY ENGINEERING VALUE, PRODUCIBILITY OR EQUIVALENT.

CED-C-5

17-4 PH CRES INVESTMENT CASTING COST-ESTIMATING DATA



CED-C-6

DICE FACTOR FOR ALUMINUM SAND CASTINGS COST ESTIMATING DATA

NOTE: DICE FACTOR EQUAL TO ONE PLUS SUM OF ALL APPLICABLE DICE FACTOR INCREMENTS IN TABLE. RESULTING DICE FACTOR USED TO MODIFY BASE CASTING COST.

DESIGN FEATURE	DICE FACTOR INCREMENT
CASTING CLASSIFICATION	
Class II	—
Class I	0.10
X-RAY GRADE	
D	—
D with C Areas	—
C	0.05
C with B Areas	0.20
B	0.50
TOLERANCE — LENGTH/WIDTH	
±0.003"/in. ±0.03" min	—
±0.0025"/in. ±0.025" min	0.10
±0.002"/in. ±0.02" min	0.20
TOLERANCES — THICKNESS	
±0.03"	—
±0.025"	0.10
±0.02"	0.20
SURFACE FINISH	
C50	—
C25	—
C20	0.15
FILLET RADII	
R = Wall Thickness	—
R = 1/2 Wall Thickness	0.10
LOCAL THICK AREAS	
Under 0.25"	—
0.25" to 0.50"	—
0.50" to 1.0"	0.05
1.0" to 2.0"	0.20
Over 2.0"	0.30
THROUGH HOLES	
None	—
Length/Diam. < 4	0.10
Length/Diam. 4–8**	0.25
BLIND HOLES	
None	—
Length/Diam. < 4	0.45
Length/Diam. 4–8**	0.80
NUMBER OF CORES	
1–3	0.10
4–7	0.30
8–11	0.50
12 UP	0.80
CORES	
Well Supported	—
Poorly Supported	0.20
SLENDERNESS RATIO (L/W OR T)	
L/W or L/T < 6	—
L/W or L/T 6–12	0.10
L/W or L/T > 12	0.25

**Consult Value or Producibility for L/D Ratios Over 8

CED-DICE-C-1

DICE FACTORS FOR ALUMINUM INVESTMENT CASTINGS COST ESTIMATING DATA

NOTE: DICE FACTOR EQUAL TO ONE PLUS SUM OF ALL APPLICABLE DICE FACTOR INCREMENTS IN TABLE. RESULTING DICE FACTOR USED TO MODIFY BASE CASTING COST.

DESIGN FEATURE	DICE FACTOR INCREMENT
CASTING CLASSIFICATION	
Class II	—
Class I	0.10
X-RAY GRADE	
D	—
D with C Areas	—
C	—
C with B Areas	0.10
B	0.50
TOLERANCE — LENGTH/WIDTH	
±0.005"/in. ±0.010" min	—
±0.004"/in. ±0.010" min	0.20
±0.003"/in. ±0.010" min	0.50
TOLERANCE-THICKNESS	
±0.010	—
±0.008	0.10
±0.005	0.20
SURFACE FINISH	
C12	—
C9	Machine
C6	Machine
FILLET RADII	
R = Wall Thickness	—
R = 1/2 Wall Thickness	0.05
LOCAL THICK AREAS	
Under 0.25" Thick	—
0.25" to 0.50"	0.10
0.50" to 1.0"	0.25
1.0" to 2.0"	0.50
Over 2.0"	1.00
THROUGH HOLES	
None	—
Length/Dia. < 4	0.10
Length/Dia. - 4-8**	0.20
BLIND HOLES	
None	—
Length/Dia. < 4	0.20
Length/Dia. - 4-8**	0.40
CORES (SOLUBLE WAX)	
None	—
1-2 Cores	0.10
3-6 Cores	0.30
SLENDERNESS (RATIO L/W OR T)	
L/W or L/T < 6	—
L/W or L/T 6-12	0.10
L/W or L/T > 12	0.25

**Consult Value or Producibility Engineer

CED-DICE-C-2

DICE FACTOR FOR 17-PH CRES INVESTMENT CASTINGS COST ESTIMATING DATA

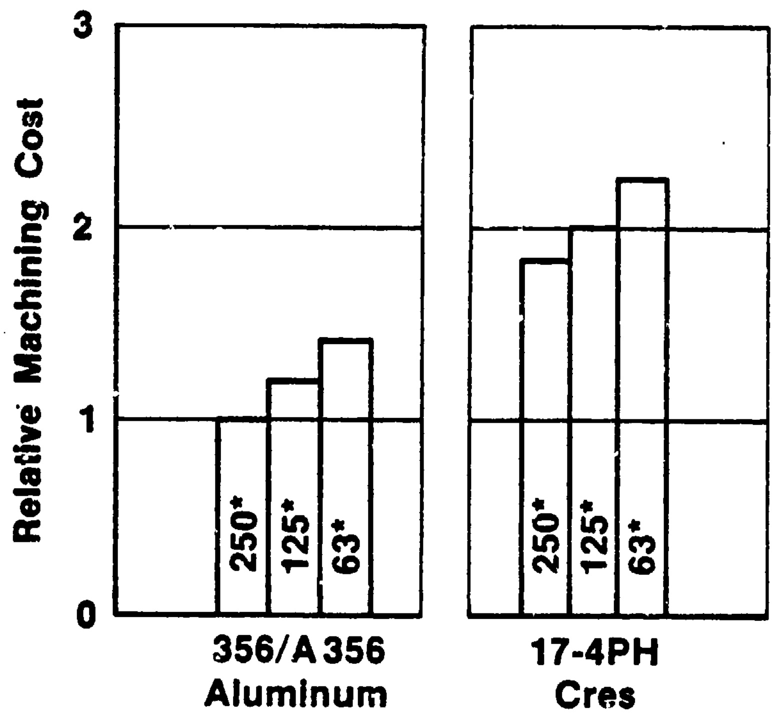
NOTE: DICE FACTOR EQUAL TO ONE PLUS SUM OF ALL APPLICABLE DICE FACTOR INCREMENTS IN TABLE. RESULTING DICE FACTOR USED TO MODIFY BASE CASTING COST.

DESIGN FEATURE	DICE FACTOR INCREMENT
CASTING CLASSIFICATION	
Class II	—
Class I	0.10
X-RAY GRADE	
D	—
D with C Areas	—
C	—
C with B Areas	0.10
B	0.50
TOLERANCE — LENGTH/WIDTH	
±0.005"/in. ±0.010" min	—
±0.004"/in. ±0.010" min	0.20
±0.003"/in. ±0.010" min	0.50
TOLERANCE-THICKNESS	
±0.010	—
±0.008	0.10
±0.005	0.20
SURFACE FINISH	
C12	—
C9	Machine
C6	Machine
FILLET RADII	
R = Wall Thickness	—
R = 1/2 Wall Thickness	0.05
LOCAL THICK AREAS	
Under 0.25" Thick	—
0.25" to 0.50"	0.15
0.50" to 1.0"	0.25
1.0" to 2.0"	0.50
Over 2.0"	1.00
THROUGH HOLES	
None	—
Length/Dia. < 4	0.10
Length/Dia. - 4-8**	0.20
BLIND HOLES	
None	—
Length/Dia. < 4	0.20
Length/Dia. - 4-8**	0.40
CORES (SOLUBLE WAX)	
None	—
1-2 Cores	0.10
3-6 Cores	0.30
SLENDERNESS (RATIO L/W OR T)	
L/W or L/T < 6	—
L/W or L/T 6-12	0.10
L/W or L/T > 12	0.25

**Consult Value or Producibility Engineer

CED-DICE-C-3

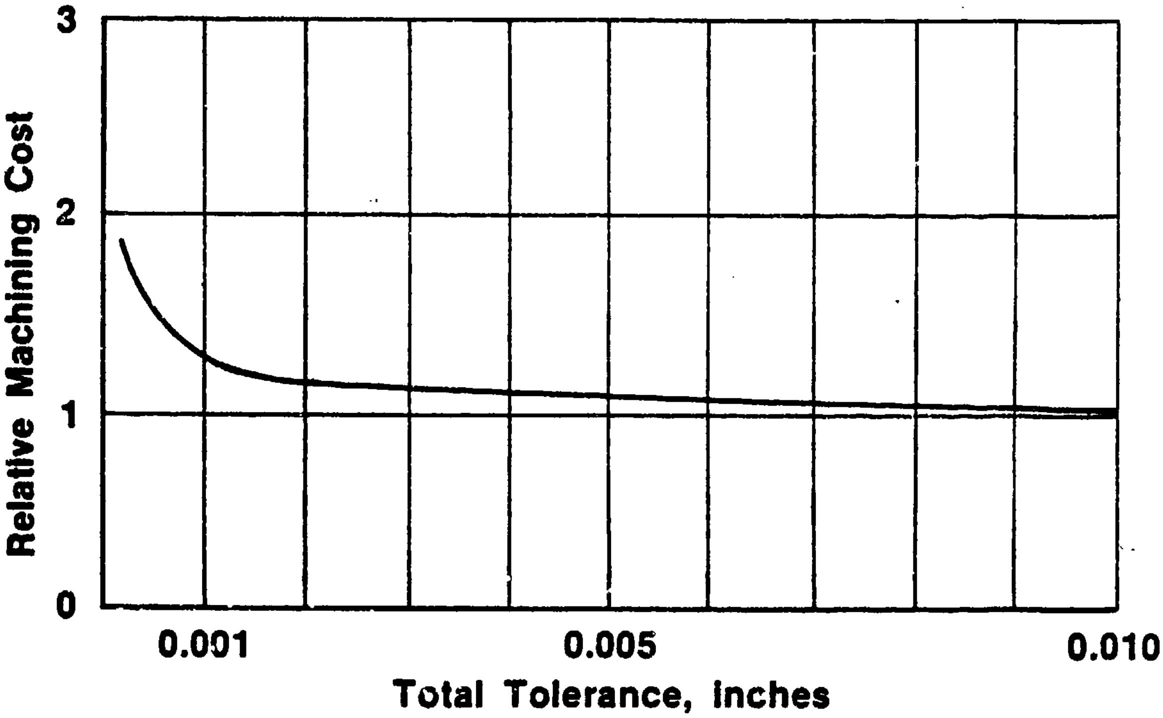
MACHINING OF CASTINGS
SURFACE FINISH
COST-DRIVER EFFECT



*Surface finish shown in micro-inches.

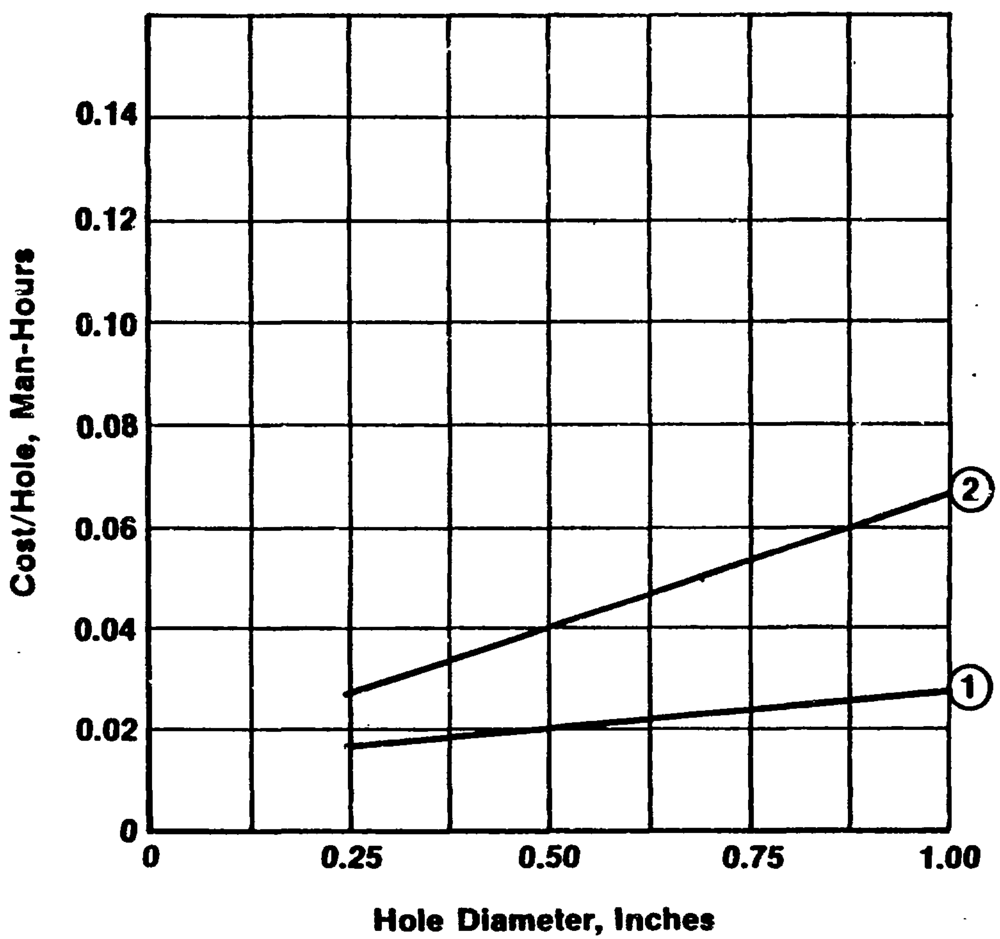
CDE-MC-I

MACHINING OF CASTINGS — DIMENSIONAL TOLERANCES COST-DRIVER EFFECT



CDE-MC-II

MACHINING OF CASTINGS
DRILL HOLES



Nonrecurring Tool Cost

NRTC = (32 + 2N) Man-Hours

Where N is the number of holes in the pattern.

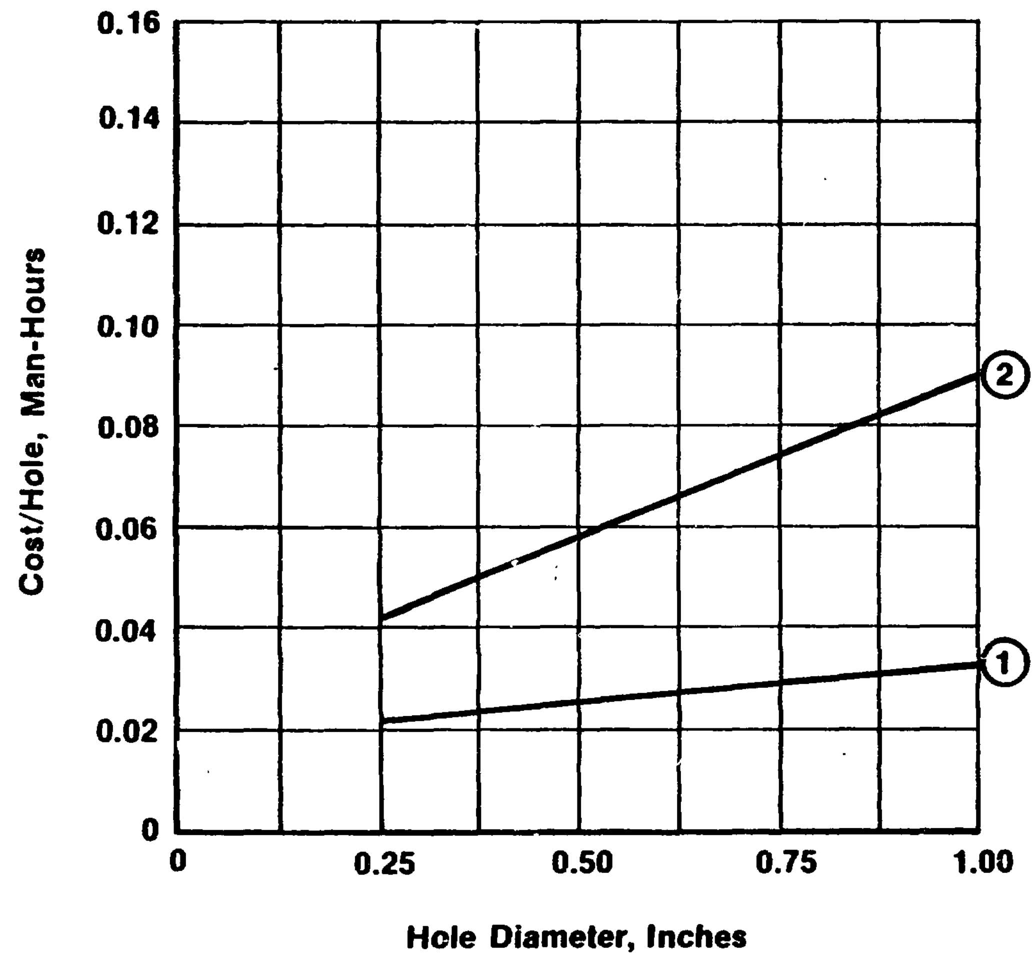
1. 356-T6 Aluminum
2. 17-4 PH CRES

Cost/Part = (Cost/Hole • N) Man-Hours

Cost data is valid for hole depths up to twice the hole diameter.

CED-MC-1

MACHINING OF CASTINGS
DRILL AND SPOTFACE HOLES



Nonrecurring Tool Cost

NRTC = (32 + 2N) Man-Hours

Where N is the number of holes in the pattern.

1 356-T6 Aluminum

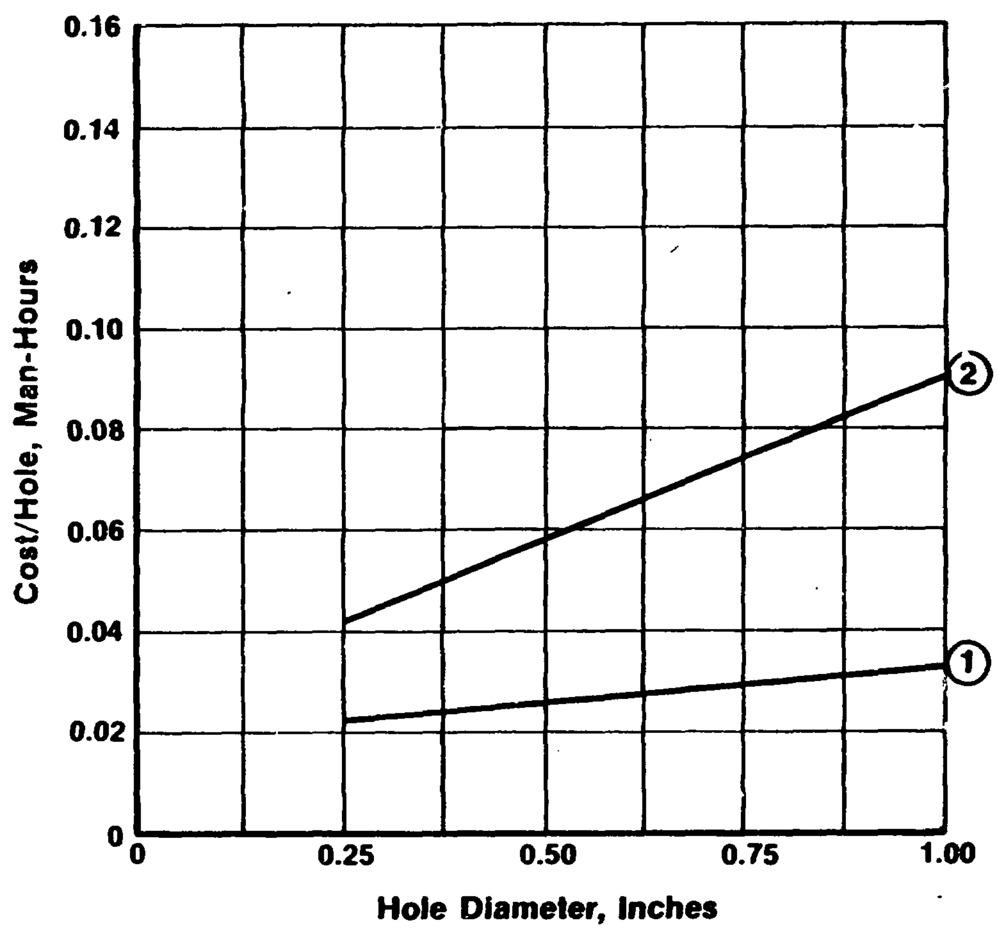
2 17-4 PH CRES

Cost/Part = (Cost/Hole • N) Man-Hours

Cost data is valid for hole depths up to twice the hole diameter.

CED-MC-2

MACHINING OF CASTINGS
DRILL AND REAM HOLES



Nonrecurring Tool Cost

NRTC = (32 + 2N) Man-Hours

Where N is the number of holes in the pattern.

1 356-T6 Aluminum

2 17-4 PH CRES

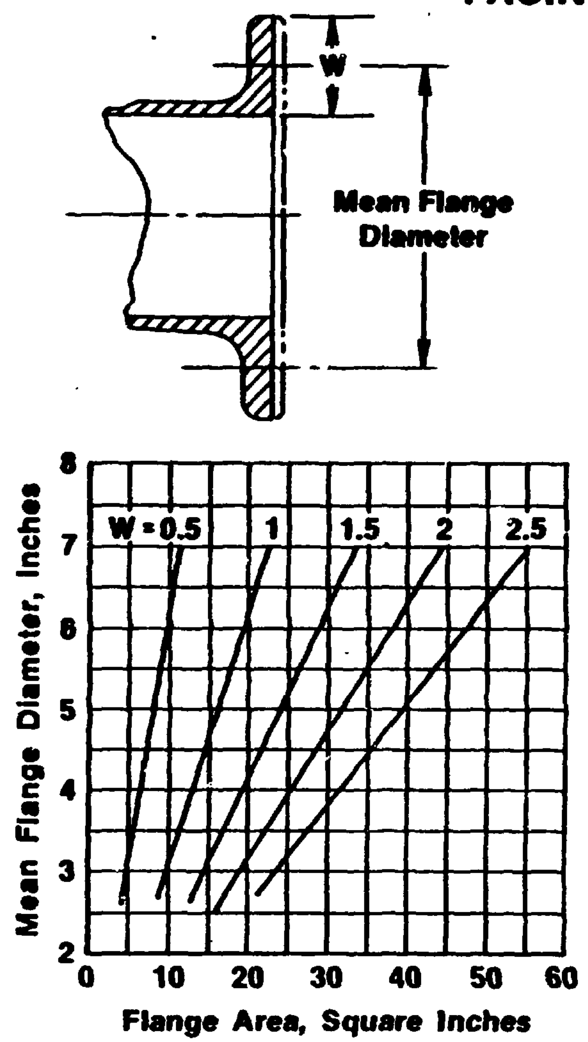
Cost/Part = (Cost/Hole • N) Man-Hours

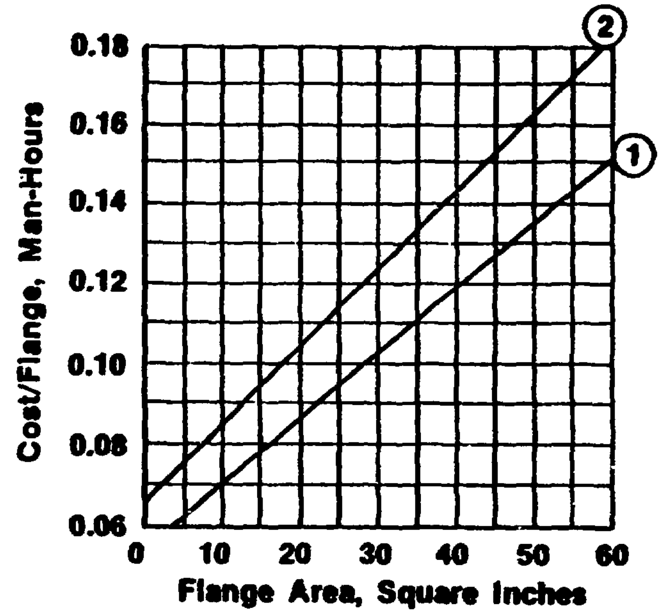
Cost data is valid for hole depths up to twice the hole diameter.

CED-MC-3

MACHINING OF CASTINGS

FACING — LATHE





(1) 356-T6 Aluminum

(2) 17-4PH CRES

Non-Recurring Tool Cost
NRTC = 45 Man-Hours

Step 1 — Obtain flange area from chart at left

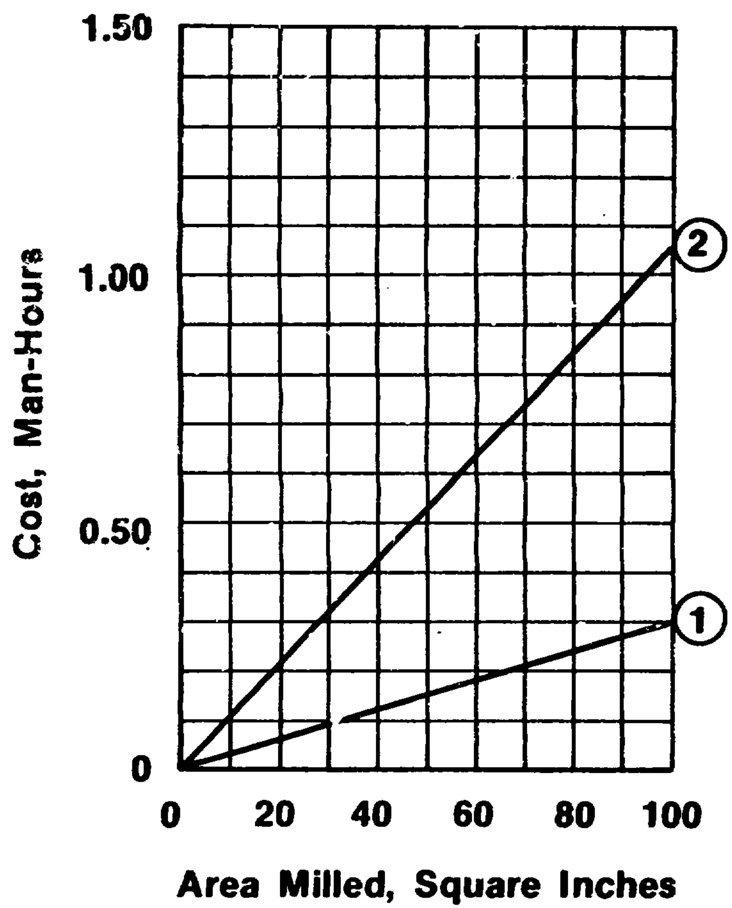
Step 2 — Obtain recurring cost/flange from chart above

Step 3 — Obtain NRTC above

CED-MC-4

MACHINING OF CASTINGS

FACE MILLING



Nonrecurring Tool Cost
NRTC = 57 Man-Hours

1 356/A 356-T6 Aluminum

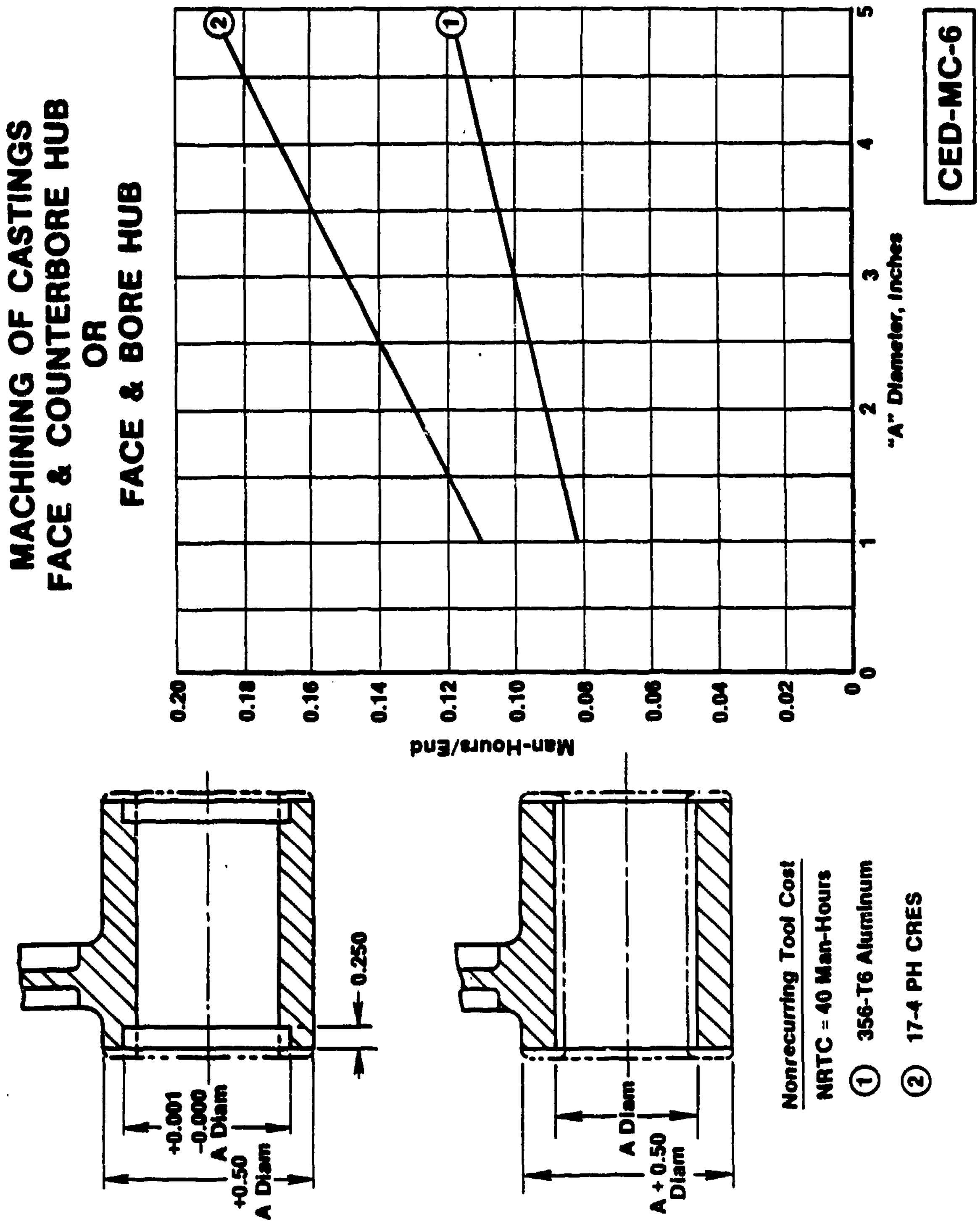
2 17-4PH CRES

Step 1 — Determine the face milling cost for <u>each</u> surface machined.

Step 2 — Add the milling costs obtained in Step 1.

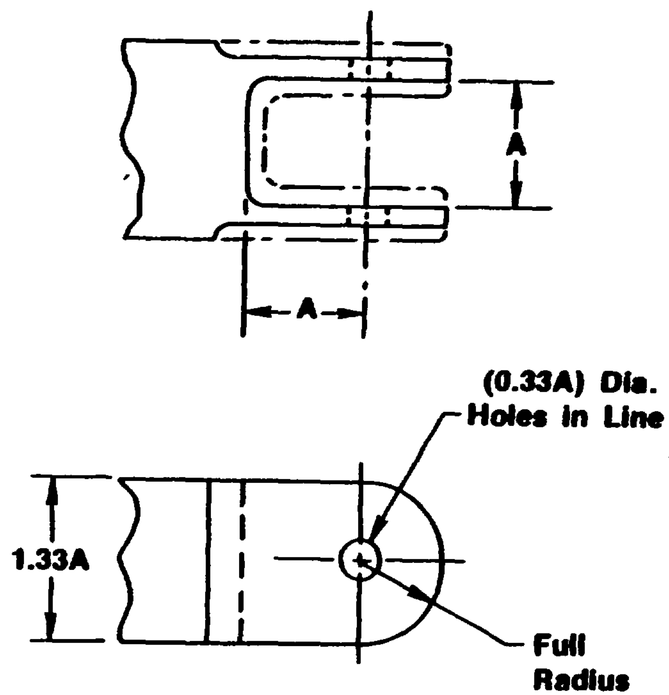
Step 3 — Obtain NRTC above.

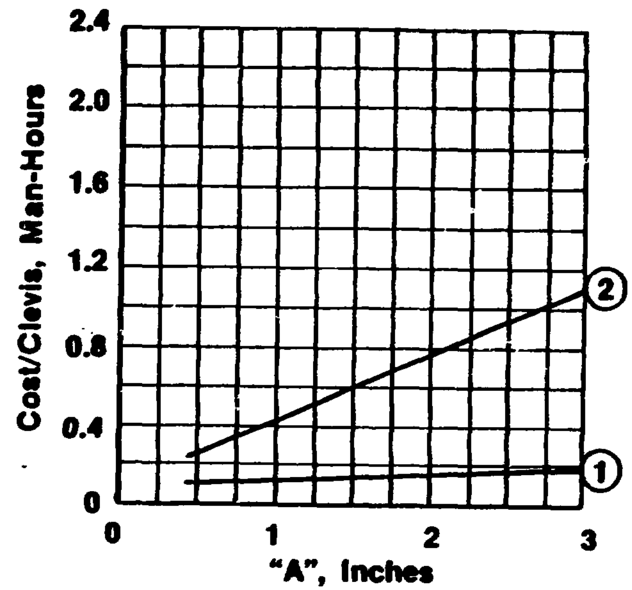
CED-MC-5


MACHINING OF CASTINGS
FACE & COUNTERBORE HUB
OR
FACE & BORE HUB
CED-MC-6
Man-Hours/End
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
1
2
3
4
5
"A" Diameter, Inches
0.250
+0.001
-0.000
A Diam
A +0.50 Diam
A Diam
A + 0.50 Diam
Nonrecurring Tool Cost
NRTC = 40 Man-Hours
1 356-T6 Aluminum
2 17-4 PH CRES

MACHINING OF CASTINGS

STRADDLE MILL, DRILL & REAM





Nonrecurring Tool Cost
NRTC = (60 + 15N) Man-Hours

Where N is the number of clevises/part.

(1) 356-T6 Aluminum
(2) 17-4PH CRES

CED-MC-7

4.5.5 Ground Rules for Castings Section

The following General and Detailed Grounds Rules for the Castings Section were developed to establish the scope of the data required and to establish guidance to MC/DG application. Ground rules are necessary and important as they promote understanding, ensure consistency, uniformity, and accuracy in generating and integrating data into the formats.

4.5.5.1 General Ground Rules

The general ground rules are categorized under the following major groupings:

(a) Casting Designs
(b) Materials
(c) Casting and Machining
(d) Facilities
(e) Data Generation - Recurring Costs (including TI&E)
(f) Castings - TI&E Recurring Costs
(g) Data Generation - Nonrecurring Costs (including TI&E)
(h) Support Function Modifiers
(i) Test and Evaluation of Data.

(a) Casting Designs

(1) The casting designs selected will be representative of parts commonly required for both small and large aircraft. The parts will be selected such that a base part forms the foundation which the designer can modify as required to achieve the desired discrete part.

(2) The castings will be selected, where possible, to develop data for more than one casting method. The data, thereby, enable the designer, using the MC/DG, to determine the most cost-competitive casting process in trade-studies.

(3) The selected castings will adequately display in CED or CDE formats, the effect on cost of DICE (e.g., thin walls, core complexity, corner radii, and structural classification).

(b) Materials

(1) The alloys selected for the cast parts will be those commonly used in the industry to enable a uniform data base to be established. The materials included are:

- Aluminum
- Titanium
- Steel.

(c) Casting and Machining

(1) Only conventional casting processes, TI&E methods, and machining methods required to produce finished parts in the configurations selected will be considered. No emerging manufacturing methods will be evaluated.

(2) A production, in contrast to a prototype environment, will be assumed for the cast machined parts.

(3) To generate an effective data base for each selected part, a factory operational sequence utilized by the casting user will be established reflecting the most economical means of fabrication of the final part. This standardized sequence will be used by each team member to determine the part cost.

(4) Requirements for tooling to machine and inspect the various parts will be identified on the data collection forms.

(d) Facilities

(1) Only standard manufacturing and TI&E facilities, available to the airframe industry, will be considered.

(e) Data Generation - Recurring Costs

(1) Recurring cost data (standard man-hours) will be generated for the complete fabrication process and will, therefore, include all the hands-on direct factory labor operations from receipt of the raw casting through storage of part in readiness for assembly into the airframe, excluding bearings,

bushings, and threaded inserts. The data will also include the raw casting TI&E data.

(2) Raw casting data presented in the MC/DG formats shall include total raw casting costs including TI&E with mechanical property verification.

(3) Data will be generated separately for aluminum sand, aluminum investment, and steel investment castings. Data will be based on box volume using team companies' historical data.

(4) Raw casting part costs will be generated for each type of casting.

(5) The DICE elements will be treated as separate cost elements and, therefore, not included in the base-part cost, but will be displayed in CED or CDE formats.

(6) Recurring tooling costs (tool maintenance, tool planning, etc.) will not be included.

(7) The quantity for which the base part and the DICE costs will be determined is at unit 200. A lot release size of 25 will be applied.

(8) The data submitted to BCL will be the raw casting part cost (man-hours or dollars) plus the DICE incremental factors associated with the discrete casting design.

(9) In developing the cost data for parts, each participating company may utilize its own proprietary improvement curves.

(10) The part casting and DICE costs will be normalized by BCL to reflect an industry team average value.

(11) For proprietary reasons, business sensitive information employed at team member contributing companies will not be presented in the MC/DG.

(12) No data provided by any team member will be disclosed to other team members, agencies, or to the public without the expressed approval of the team member.

(f) Castings - TI&E Recurring Costs

(1) The general ground rules for castings (paragraphs 2, 6, 7, 9, 11, and 12) also apply to the casting TI&E. The following are added for casting TI&E.

(2) Recurring cost data will be generated for TI&E functions required from the supplier to receiving stores, including outside laboratories.

(3) TI&E cost data for the raw castings only will be included.

(4) Costs will be presented in 1980 dollars.

(5) CED and/or CDE formats will display the following TI&E costs and data:

- Penetrant inspection
- Radiographic inspection
- Magnetic particle inspection
- Mechanical properties verification
- Chemistry verification
- Dimensional inspection.

(6) TI&E cost data will be normalized by BCL to reflect an industry team average value.

(g) Data Generation - Nonrecurring Costs for Raw Castings and TI&E

(1) Tooling costs will be generated for each part type. TI&E fixture costs will be the responsibility of the user company where applicable.

(2) The cost of production tooling will be restricted to contract or project tools only for presentation in the MC/DG.

(3) First article TI&E cost will be generated and displayed as part of the nonrecurring tooling cost.

(4) Nonrecurring tooling costs (NRTC) generated by the team companies will be normalized by BCL for presentation in the MC/DG.

(h) Support Function Modifiers

(1) Additional effort other than factory labor and TI&E, i.e., planning and tool maintenance, will be excluded from the part cost data supplied to BCL. Other modifiers may be included later by the MC/DG users at airframe companies.

(i) Test and Evaluation of Data

(1) Test and confirmation of the formats and integrated data will be accomplished by one team member. Each of the remaining team members will be provided with the evaluation. Any anomalies will be resolved and modifications incorporated as appropriate.

4.5.5.2 Detailed Ground Rules

The detailed ground rules are categorized under the following major groups:

(a) Casting designs
(b) Materials
(c) Classification
(d) Data generation - recurring costs
(e) TI&E functions.

(a) Casting Designs

(1) Each team member will review applicable casting designs and tabulate required data on the data collection sheets developed by the team.
(2) Selected typical designs will be utilized for determination of user-associated costs (e.g., machining and finishing).
(3) The castings analyzed by each team member will be classified by complexity type. This classification will be designated on the data collection form submitted to BCL.

Each team member company will submit to BCL a definition or a drawing or sketch illustrating their proposed understanding of these classifications.

(b) Materials

(1) The materials and processes selected for castings are:

- Aluminum
  - A356 per MIL-A-21180 or company equivalent specification (sand or investment)
  - 356 or A356 per QQ-A-601 (sand castings)
  - 357 per MIL-A-21180 (sand castings)
- Steel
  - 17-4PH CRES per AMS-5342, 5343, and 5344 or company equivalent specification
- Titanium
  - Ti-6Al-4V Cond A (vacuum cast, investment or rammed graphite).

(c) Classification

(1) The basic use classification (Class I or II) shall be reported for each casting.

(2) The casting quality shall comply with MIL-C-6021 or equivalent user company specification for X-ray grade.

(3) The radiographic standard grade (A, B, C, or D) basis for each casting shall be reported. Special testing (e.g., static tests) used to complement inspection shall be identified.

(d) Data Generation - Recurring Costs

(1) Data indicated on the data collection sheet will be gathered, as available, for the raw casting. TI&E costs associated with the raw casting will be established separately.

(2) Machining (including cleaning and protective coatings) will be reported separately for typical parts utilizing standards and learning (improvement) curves, if applicable. TI&E costs for the user operations will not be included as a part of this task.

(3) Machining cost data will be developed for the following basic machining parameters:

(a) Counter-bore and face-hub

(b) Drilled holes, drilled and reamed holes, drilled and spot-faced holes

(c) Circular-flange facing (lathe), flat-faced (mill)

(d) Straddle-mill and drill-clevis fittings.

(4) Available cost data for titanium castings obtained from suppliers by BCL will be analyzed and formatted.

(e) TI&E Functions

(1) The following are typical TI&E operations that will be evaluated:

- Chemistry
- Mechanical properties
  - Separately cast test bars
  - Coupons from castings (prolongation)
  - Dissected castings
- Dimensional
- Radiographic
- Penetrant/magnetic
- Surface finish
- Pressure test
- Static test (proof of design).

4.6 Forging Section

This section contains format selection aids, identification of the types of parts analyzed for data to determine the manufacturing man-hour data, examples of how the data are utilized in airframe design and a set of formats generated. These formats include cost-driver effects (CDE), cost estimating data (CED), and designer-influenced cost elements (DICE).

4.6.1 Format Selection Aids

Format selection aids are presented to provide the user with a building-block approach to determine manufacturing cost data for alternative designs or processes. The designer can review the format selection trees and identify those areas that have an impact on his design. The formats provide cost-driver effects (CDE) for qualitative guidance to lowest cost and cost-estimating data (CED) in man-hours for conducting trade studies.

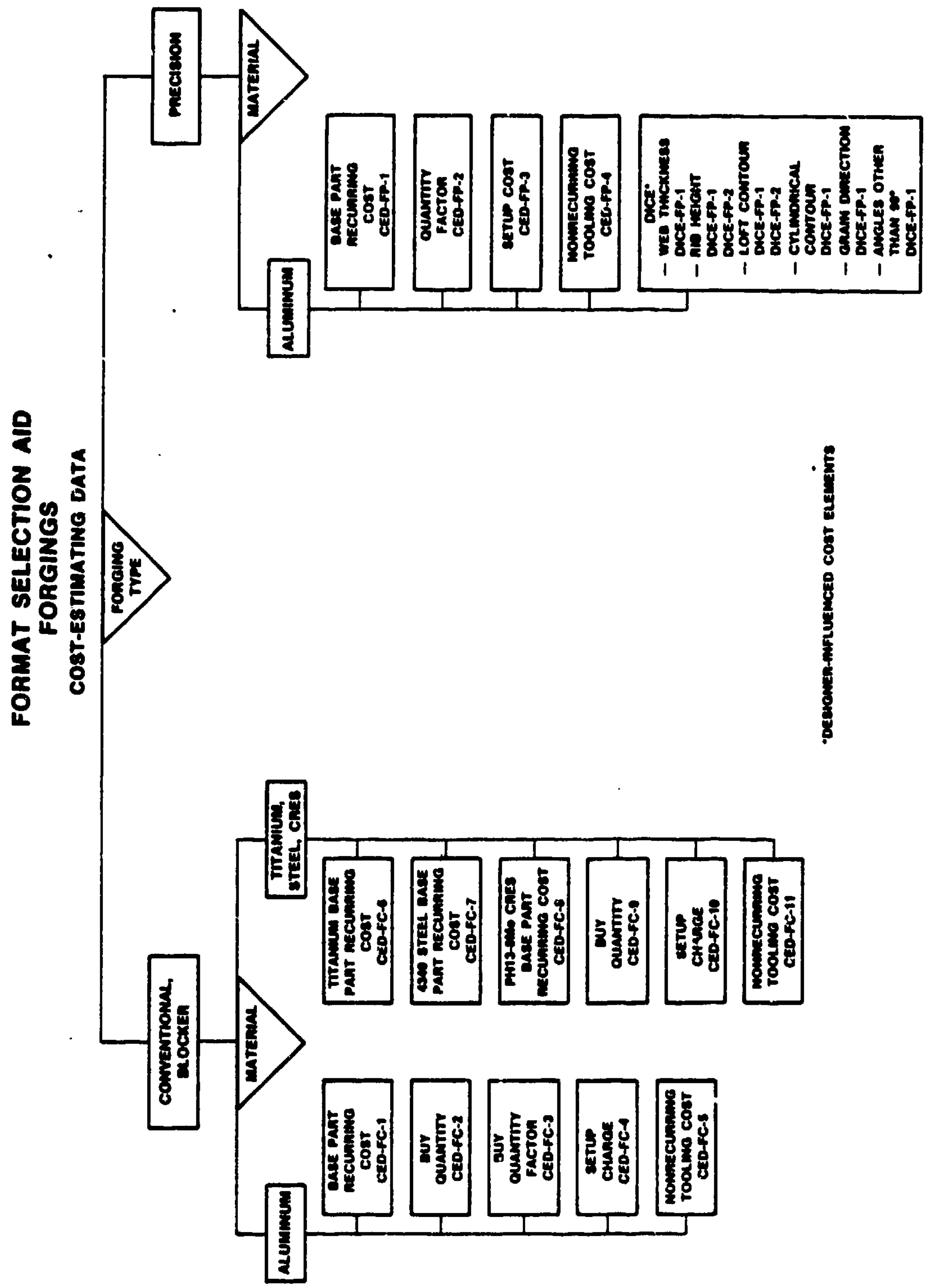

FORMAT SELECTION AID
FORGINGS
COST-ESTIMATING DATA
FORGING TYPE
CONVENTIONAL, BLOCKER
PRECISION
MATERIAL
ALUMINUM
TITANIUM, STEEL, CRES
BASE PART RECURRING COST CED-FC-1
BUY QUANTITY CED-FC-2
BUY QUANTITY FACTOR CED-FC-3
SETUP CHARGE CED-FC-4
NONRECURRING TOOLING COST CED-FC-5
TITANIUM BASE PART RECURRING COST CED-FC-6
4340 STEEL BASE PART RECURRING COST CED-FC-7
PH13-8Mo CRES BASE PART RECURRING COST CED-FC-8
BUY QUANTITY CED-FC-9
SETUP CHARGE CED-FC-10
NONRECURRING TOOLING COST CED-FC-11
MATERIAL
ALUMINUM
BASE PART RECURRING COST CED-FP-1
QUANTITY FACTOR CED-FP-2
SETUP COST CED-FP-3
NONRECURRING TOOLING COST CED-FP-4
DICE*
— WEB THICKNESS DICE-FP-1
— RIB HEIGHT DICE-FP-1 DICE-FP-2
— LOFT CONTOUR DICE-FP-1 DICE-FP-2
— CYLINDRICAL CONTOUR DICE-FP-1
— GRAIN DIRECTION DICE-FP-1
— ANGLES OTHER THAN 90° DICE-FP-1
*DESIGNER-INFLUENCED COST ELEMENTS

FIGURE 4.6-1

FORMAT SELECTION AID
FORGINGS
COST-DRIVER EFFECTS

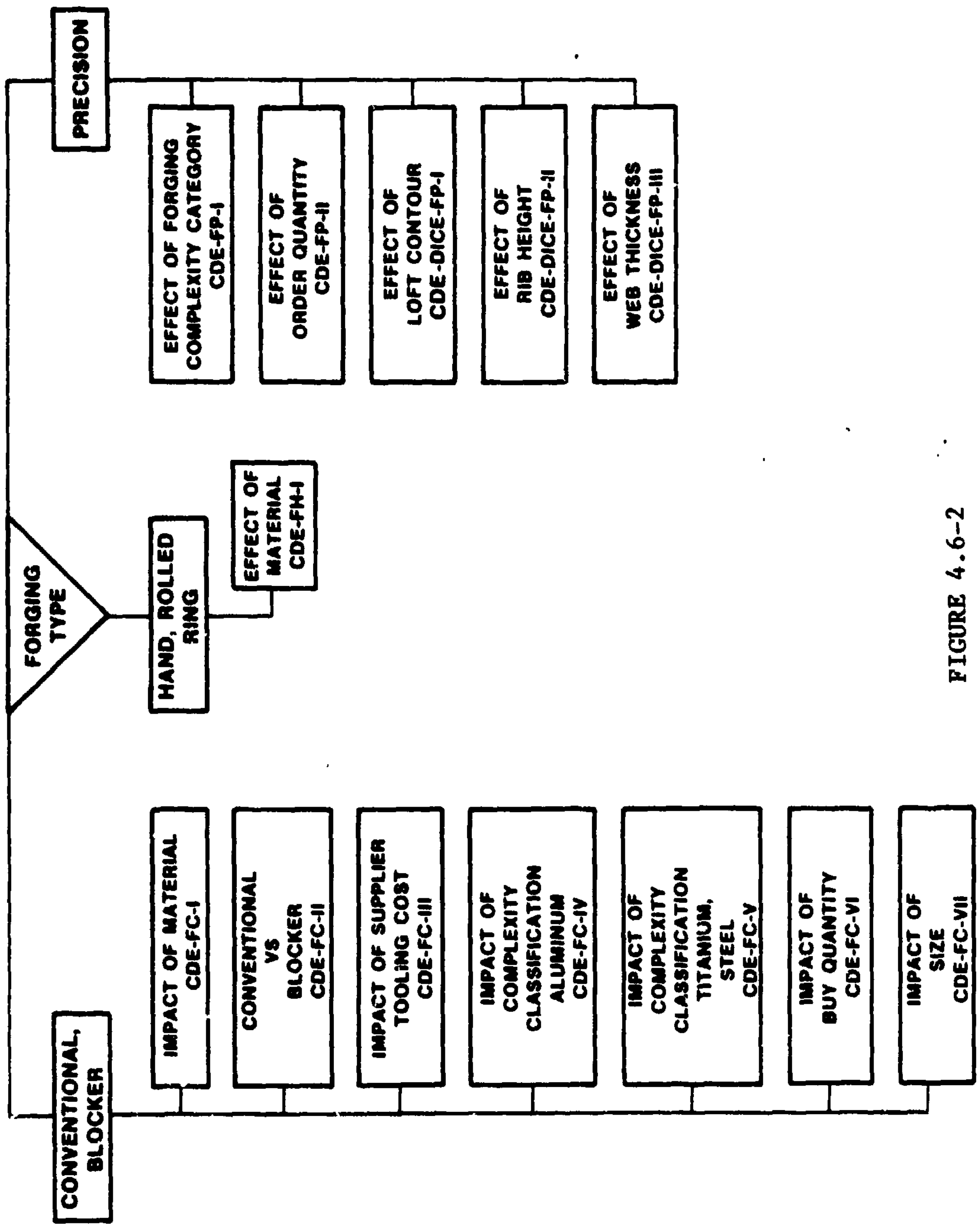


FIGURE 4.6-2

FORMAT SELECTION AID

MACHINING OF FORGINGS

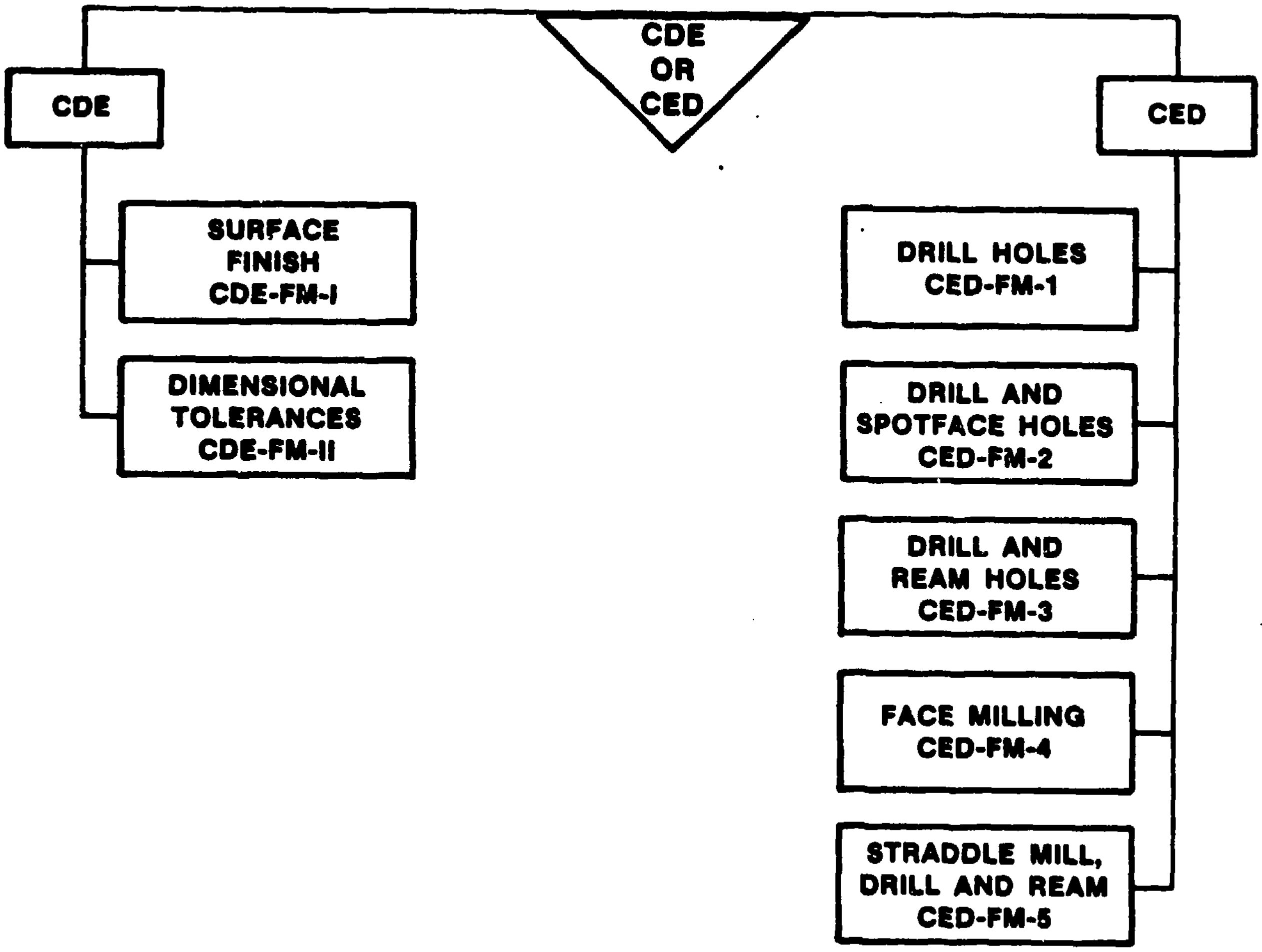


FIGURE 4.6-3

4.6.2 Example of Utilization

This example demonstrates how the data generated are utilized on a specific design problem. The example shows how to identify applicable formats, how to extract data from the formats, and provides a discussion on how the data are used to determine the part cost in man-hours or dollars. The MC/DG cost worksheet can be used to record the cost data for easy reference and to determine the total program cost. (Figure 3-3). Worksheets for forgings and also machining of forgings are provided in Tables 4.6-2 and 4.6-3.

4.6.2.1 Utilization Example for Aluminum Precision Forging

Problem Statement

Determine the cost, in 1982 dollars per part, for the aluminum precision forging shown in the sketch on the following page. Test, inspection and evaluation (TI&E) costs are to be included in the cost of the forging. The dimensions are as shown in the part sketch. The design quantity is to be 200 units and the buy quantity is 50 units per buy.

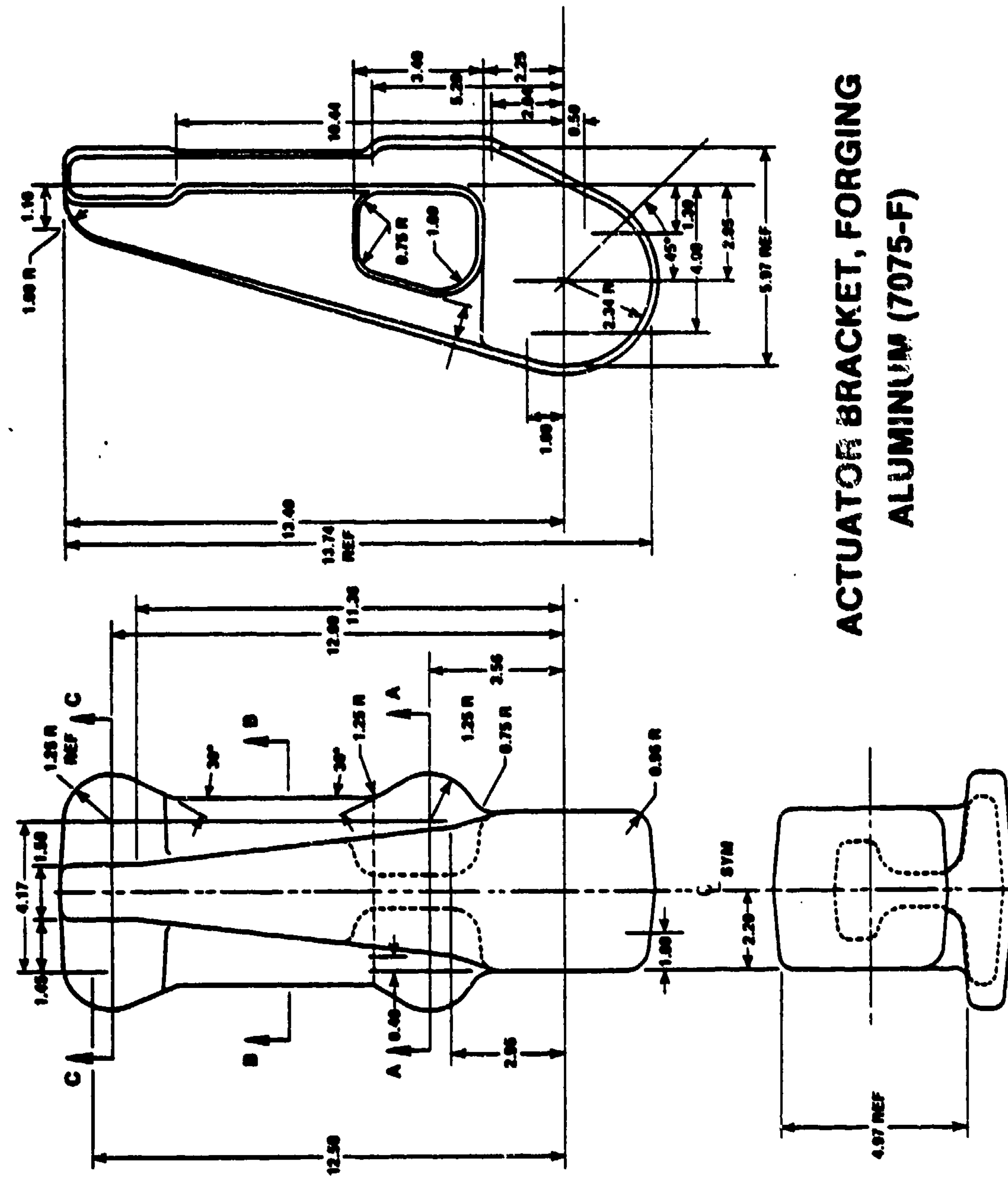
Procedure

The following procedure is used to determine the forging cost.

1. Obtain a copy of the MC/DG Forgings Cost Worksheet, and begin to fill in the necessary information.
2. Utilize the Format Selection Aid for Forgings Cost-Estimating Data (Figure 4.6-1).
3. Determine the formats to use. For this part, the following formats, which are included in this section, are required:
   - Base Part Manufacture
     - Base Part Recurring Cost: CED-FP-1 (Figure 4.6-6)
     - Quantity Factor: CED-FP-2 (Figure 4.6-7)
     - Setup Cost - CED-FP-3 (Figure 4.6-8)
     - Nonrecurring Tooling Cost: CED-FP-4 (Figure 4.6-9)
   - Designer-Influenced Cost Elements
     - Web Thickness: DICE-FP-1 (Figure 4.6-10)
     - Rib Height: DICE-FP-1 (Figure 4.6-10)
       DICE-FP-2 (Figure 4.6-11).
4. Study the formats to determine the required parameters and conditions and relate these to the part. The following parameters and conditions are required.

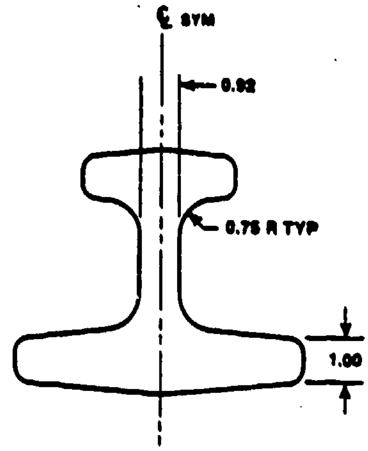
Format	Parameters, Conditions
CED-FP-1	Plan area Complexity classification
CED-FP-2	Order quantity
CED-FP-3 (Fig. 4.6-8)	Complexity classification Plan area Order quantity
CED-FP-4 (Fig. 4.6-9)	Plan area Complexity classification
DICE-FP-1 (Fig. 4.6-10)	Design feature Plan area Web thickness Rib height
DICE-FP-2 (Fig. 4.6-11)	Design feature Rib height.

5. Read the required data from the formats and enter the data onto the Forgings Cost Worksheet.
6. Perform the calculations indicated on the worksheet for recurring and nonrecurring cost.
7. Utilize the Format Selection Aid for Test, Inspection and Evaluation (TI&E) of Forgings (page 4.7.4-2).
8. Determine the format to use. In this case, Format CED-TI&E-F-1 (Fig. 4.6-12) is required.
9. Study the format to determine necessary parameters and conditions. For CED-TI&E-F-1, forging type and inspection type are required.
10. From CED-TI&E-F-1, read the TI&E costs.
    - The first article inspection cost is the cost of one forging plus $300.
    - The production TI&E cost is the cost of one forging plus $300 per lot.
11. Substitute these values into the appropriate spaces on the worksheet and perform the indicated calculations to determine the program cost of TI&E.
12. Perform the calculations indicated in the Cost Summary section of the worksheet to determine the total cost per part of the forging. For this part, the total cost per part is $218.

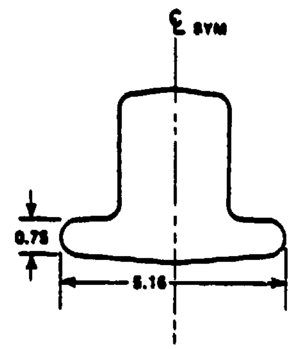


ACTUATOR BRACKET, FORGING
ALUMINUM (7075-F)

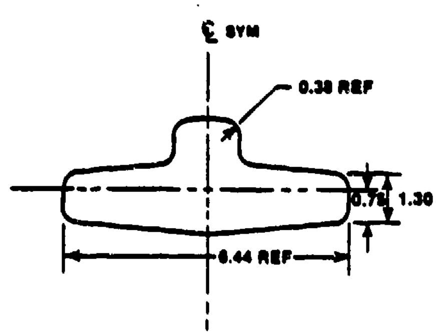
FIGURE 4.6-4. PART ANALYZED



SECTION A-A



SECTION B-B



SECTION C-C

FIGURE 4.6-5. PART ANALYZED

ALUMINUM PRECISION FORGING BASE PART COST

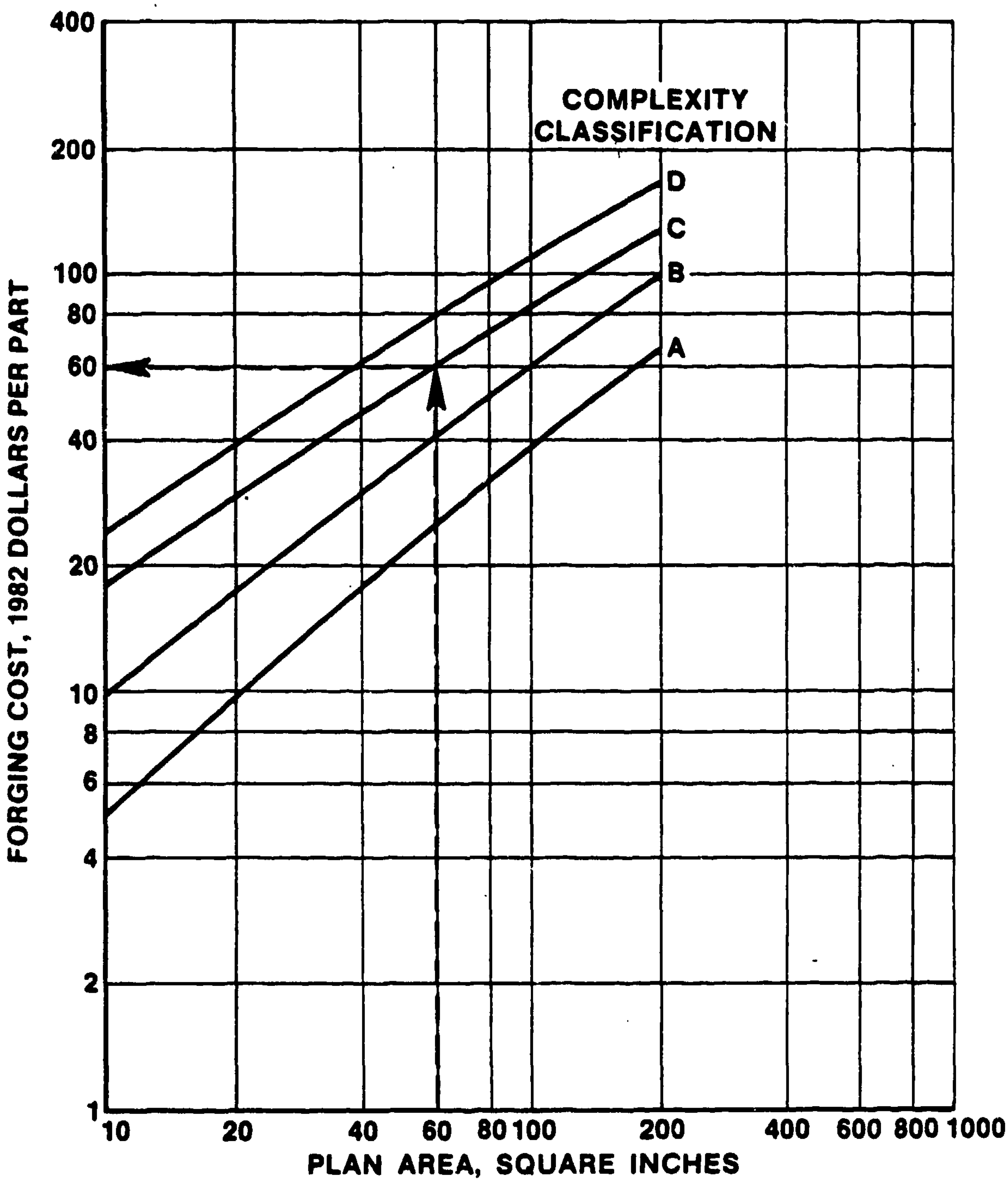


FIGURE 4.6-6. FORMAT USED IN EXAMPLE

CED-FP-1

ALUMINUM PRECISION FORGINGS QUANTITY FACTOR

ORDER QUANTITY	FACTOR
UP TO 25	1.6
26 TO 50	1.35
51 TO 100	1.2
101 TO 200	1.1
201 UP	1.0

NOTE: IF ORDER QUANTITY IS NOT KNOWN, USE 1.35.

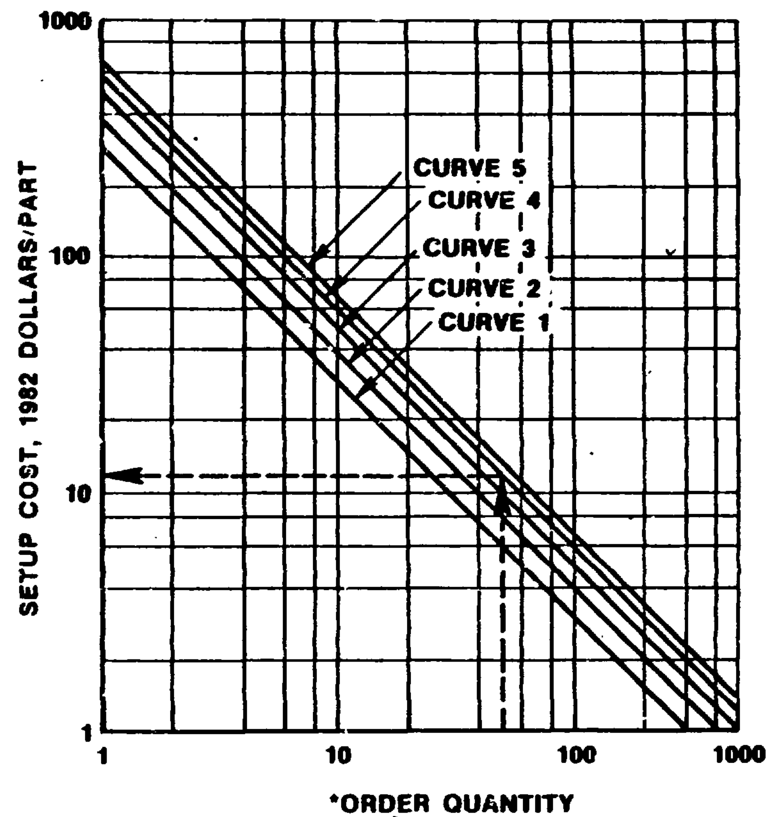
FIGURE 4.6-7. FORMAT USED IN EXAMPLE

CED-FP-2

ALUMINUM PRECISION FORGINGS SETUP COST

CATEGORY	PLAN AREA	USE CURVE
A & B	UP TO 10 SQ. IN	1
A & B	11 TO 25 SQ. IN.	2
C & D	UP TO 10 SQ. IN.	2
A & B	26 TO 100 SQ. IN.	3
C & D	11 TO 25 SQ. IN.	3
A & B	101 & UP SQ. IN.	4
C & D	26 TO 100 SQ. IN.	4
C & D	101 & UP SQ. IN.	5

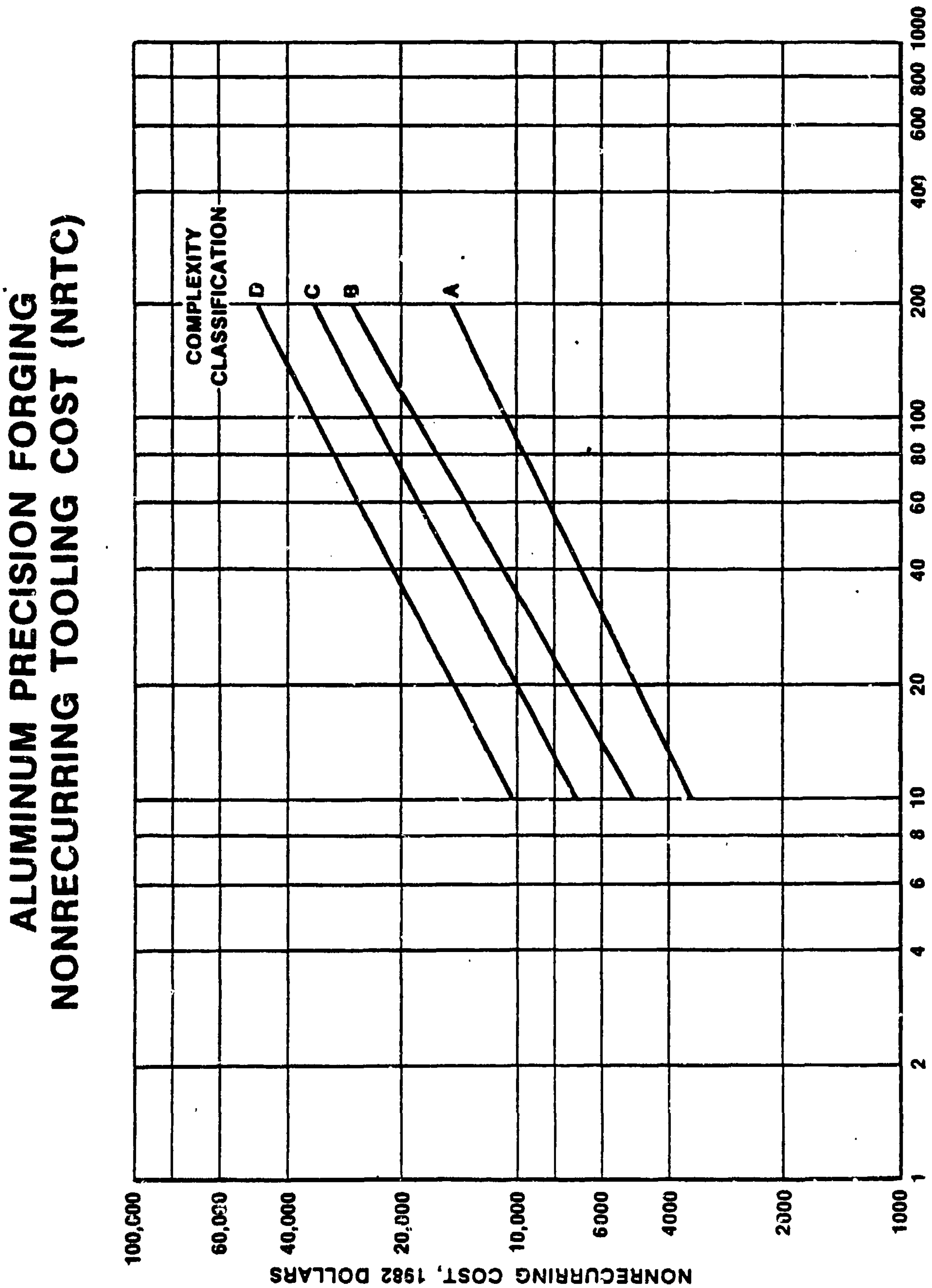
FORGING PRESS SETUP COST



*NOTE: IF ORDER QUANTITY IS NOT KNOWN, USE 50.

CED-FP-3

FIGURE 4.6-8. FORMAT USED IN EXAMPLE



CED-FP-4

FIGURE 4.6-9. FORMAT USED IN EXAMPLE

ALUMINUM PRECISION FORGING RECURRING COST DICE FACTOR

DESIGN FEATURE		DICE FACTOR
WEB THICKNESS		
PLAN AREA	WEB THICKNESS	
UP TO 50 SQ. IN.	0.120	—
	0.090	1.3
51 TO 150 SQ. IN.	0.150	—
	0.120	1.3
151 TO 200 SQ. IN.	0.180	—
	0.150	1.3
RIB HEIGHT		
UP TO 1.50		—
1.51 TO 2.00		1.1
2.01 TO 3.00		1.2
3.01 TO 4.00		1.5
4.01 TO 5.00		1.7
5.01 TO 6.00		1.9
SPECIAL CONDITIONS		
LOFT CONTOUR		1.2
CYLINDRICAL CONTOUR		1.2
GRAIN DIRECTION		1.2
ANGLES OTHER THAN 90 DEGREE TO BASE		1.2

NOTE: IF MORE THAN ONE (1) DESIGN FEATURE IS APPLICABLE, USE ONLY THE HIGHEST.

FIGURE 4.6-10 FORMAT USED IN EXAMPLE

DICE-FP-1

ALUMINUM PRECISION FORGING NONRECURRING COST DICE FACTOR

DESIGN FEATURE	DICE FACTOR
RIB HEIGHT	
UP TO 1.50	—
1.51 TO 2.00	1.05
2.01 TO 3.00	1.10
3.01 TO 4.00	1.25
4.01 TO 5.00	1.35
5.01 TO 6.00	1.45
LOFT CONTOUR	1.50

NOTE: IF MORE THAN (1) DESIGN FEATURE IS APPLICABLE USE ONLY THE HIGHEST.

DICE-FP-2

FIGURE 4.6-11. FORMAT USED IN EXAMPLE

ALUMINUM, TITANIUM, STEEL, CRES FORGINGS TEST, INSPECTION, AND EVALUATION

INSPECTION	HAND AND ROLLED RING FORGINGS	BLOCKER, CONVENTIONAL & PRECISION FORGINGS
FIRST ARTICLE (NONRECURRING)	NOT APPLICABLE	COST OF ONE (1) FORGING + PLAN AREA — 1982 $ 100 SQ. IN. — 300 101-500 SQ. IN — 400 501-1,000 SQ. IN. — 500 1,001 up — 600
PRODUCTION	$300/LOT	COST OF ONE (1) FORGING + $300 PER LOT.

NOTE: COSTS IN 1982 DOLLARS ARE FOR BOTH SUPPLIER AND USER. ULTRASONIC INSPECTION COSTS TO BE ADDED.

FIGURE 4.6-12. FORMAT USED IN EXAMPLE

CED-TI&E-F-I

ALUMINUM, TITANIUM, STEEL,CRES FORGINGS TEST, INSPECTION, AND EVALUATION

INSPECTION	HAND AND ROLLED RING FORGINGS	BLOCKER, CONVENTIONAL & PRECISION FORGINGS
FIRST ARTICLE (NONRECURRING)	NOT APPLICABLE	COST OF ONE (1) FORGING + PLAN AREA — 1982 $ 100 SQ. IN. — 300 101-500 SQ. IN — 400 501-1,000 SQ. IN. — 500 1,001 up — 600
PRODUCTION	$\boxed{\$300/LOT}$	COST OF ONE (1) FORGING + $300 PER LOT.

NOTE: COSTS IN 1982 DOLLARS ARE FOR BOTH SUPPLIER AND USER. ULTRASONIC INSPECTION COSTS TO BE ADDED.

FIGURE 4.6-13. FORMAT USED IN EXAMPLE

CED-TI&E-F-I

TABLE 4.6-1

FORGING COST WORKSHEET

TITLE: **DESIGN QUANTITY:** **LOT QUANTITY:** **DESIGNER:** **DATE:**

TYPE	MATERIAL	HAND/RING	BLOCKER/CONV.	CONV./PRECISION	PRECISION	TEST, INSP. & EVALUATION
Hand ____ Ring ____ Blocker ____ Conv. ____ Precision ____	Aluminum ____ Ti6Al-4V ____ 4340 Air ____ Vacuum ____ PH Cres 15-5 ____ 13-8 ____	Size L ____ OD ____ W ____ ID ____ T ____ T ____ Weight ____ Lb Base Cost $ ____ /Lb	Weight ____ Lb Base Cost $ ____ /Lb Setup Cost $ ____ /Lot Size L ____ W ____ H ____ Die Factor ____	Category A ____ B ____ C ____ D ____ Plan Area ____ Sq. In. Buy-Quantity Factor ____	Base Cost $ ____ Ea. Setup Cost $ ____ Ea. DICE Factor Rec. ____ Nonrec. ____	First Article Cost One Forging + $ ____ = $ ____ Production Cost/Lot One Forging + $300 = $ ____ Ultrasonic Insp. $ ____ Each Inflation Factor ____

RECURRING COST

Hand/Ring Forging

Cost/Part = Weight x Base Cost x Inflation Factor

= ______ Lbs x $ ______ /Lb x ______ = $ ______ Each

Blocker Forging

$$\text{Cost/Part} = \left[\text{Weight} \times \text{Base Cost} \times 0.8 \times \frac{\text{Buy Qty.}}{\text{Factor}} + \frac{\text{Setup/Lot}}{\text{Buy Qty.}}\right] \frac{\text{Inflation}}{\text{Factor}}$$

$$= \left[\_\_\_\_\ \text{Lb} \times \$\ \_\_\_\_\ /\text{Lb} \times 0.8 \times \_\_\_\_ + \frac{\$\ \_\_\_\_}{(\qquad)}\ /\text{Lot}\right]\ \_\_\_\_$$

= $ ______ Each

Conventional Forging

$$\text{Cost/Part} = \left[\text{Weight} \times \text{Base Cost} \times \frac{\text{Buy Qty.}}{\text{Factor}} + \frac{\text{Setup/Lot}}{\text{Buy Qty.}}\right] \frac{\text{Inflation}}{\text{Factor}}$$

$$= \left[\_\_\_\_\ \text{Lb} \times \$\ \_\_\_\_\ \text{Lb} \times \_\_\_\_ + \frac{\$\ \_\_\_\_}{(\qquad)}\ /\text{Lot}\right]\ \_\_\_\_$$

= $ ______ Each

Precision Forging

$$\text{Cost/Part} = \left[\text{Base Cost} \times \frac{\text{Rec. DICE}}{\text{Factor}} \times \frac{\text{Buy Qty.}}{\text{Factor}} + \text{Setup}\right] \frac{\text{Inflation}}{\text{Factor}}$$

$$= \$\left[\_\_\_\_\ \text{Each} \times \_\_\_\_ \times \_\_\_\_ + \$\ \_\_\_\_\ \text{Each}\right]\ \_\_\_\_$$

= $ ______ Each

NONRECURRING COST

Blocker / Conventional Forging

$$\text{Tool Cost} = (L + 12")(W + 12")(H + 14")\ \frac{\text{Die}}{\text{Factor}} \times \frac{\text{Inflation}}{\text{Factor}}$$

= (______ +12") x (______ +12") x (______ +14") x ______ x ______

= $ ______

Precision Forging

$$\text{Tool Cost} = \text{Base Tool Cost} \times \frac{\text{Nonrec. DICE}}{\text{Factor}} \times \frac{\text{Inflation}}{\text{Factor}}$$

= ______ x ______ x ______

= $ ______

Cost Summary

$$\text{Program Cost} = \text{Cost/Part} \times \frac{\text{Design}}{\text{Quantity}} + \text{Tool Cost} + \frac{\text{First Article}}{\text{TI\&E Cost}} + \frac{\text{Prod TI\&E}}{\text{Cost/Lot}} \times \frac{\text{Design Qty.}}{\text{Lot Qty.}}$$

$$= \$\ \_\_\_\_ \times \_\_\_\_ + \$\ \_\_\_\_ + \$\ \_\_\_\_ + \$\ \_\_\_\_ \times \frac{(\qquad)}{(\qquad)}$$

$$= \$\ \_\_\_\_\quad \text{Total Cost/Part} = \frac{\text{Program Cost}}{\text{Design Qty.}} = \$\ \_\_\_\_\ \text{Each}$$

TABLE 4.6-2

MACHINING COST WORKSHEET FOR FORGINGS

MACHINING FEATURE	FORMAT	RECURRING COST (MAN-HOURS)	NONRECURRING TOOLING COST (MAN-HOURS)
HOLES: NO. ______ SIZE ______ DRILL DRILL & SPOTFACE DRILL & REAM			
FACE MILLING AREA MILLED ______ IN^2			
CLEVIS-STR. MILL, DRILL, AND REAM NO. ______ SIZE ______			
MACHINING COST (UNIT 200) PER PART			
LEARNING CURVE FACTOR (SEE BELOW)			
LABOR RATE		$ /HR	$ /HR
RECURRING MACHINING COST/PART*		$	
NONRECURRING TOOLING COST (NRTC)			$

*RECURRING MACHINING COST/PART =
UNIT 200 COST/PART × LEARNING CURVE FACTOR × LABOR RATE.

DESIGN QUANTITY	LEARNING CURVE FACTOR	DESIGN QUANTITY	LEARNING CURVE FACTOR
1	2.25	200	1.17
10	1.79	350	1.08
25	1.59	500	1.02
50	1.44	750	0.96
100	1.30	1000	0.92

90% LEARNING CURVE FACTOR TO CONVERT UNIT 200 FORMAT COST TO CUMULATIVE AVERAGE COST FOR VARIOUS DESIGN QUANTITIES.

PROGRAM COST =
(______ × ______ + ______) × ______ = ______
RECURRING MACHINING COST, DESIGN QUANTITY, NRTC, INFLATION FACTOR**

TOTAL COST PER PART = PROGRAM COST/DESIGN QUANTITY = ______ / ______ = ______

**INFLATION FACTOR SUPPLIED BY USER'S COMPANY.

4.6.3 Parts Analyzed

The data for the forgings are applicable for parts such as shown in Figures 4.6-13 to 4.6-24. It will be noted that the parts have been classified as A, B, C, and D. Conventional and precision forgings are also indicated. The classifications are classified as follows:

CLASSIFICATION LEVELS OF COMPLEXITY FOR CONVENTIONAL FORGINGS

A. Simple cylindrical, rectangular, and square shapes with minor features; and "L" shapes.

B. Beams and frame sections such as "T" shapes, cruciform shapes, and channel cross-sectional shapes; open end shapes; and shallow flat boxes and bath tubs.

C. Thin, flat or moderately contoured shapes (other than round).

D. Box shapes, "H" shapes with enclosing ribs, inter- and circumscribing ribs, and circular wheel shapes with enclosing ribs.

CLASSIFICATION LEVELS OF COMPLEXITY FOR ALUMINUM PRECISION FORGINGS

A. Simple cylindrical, rectangular, and square shapes with minor features; "L" shapes; three-sided corner clips; and thin, flat, or moderately contoured shapes.

B. Beams and frame sections such as "T" shapes, cruciform shapes, and channel cross-sectional shapes; open end shapes; and shallow flat boxes and bath tubs.

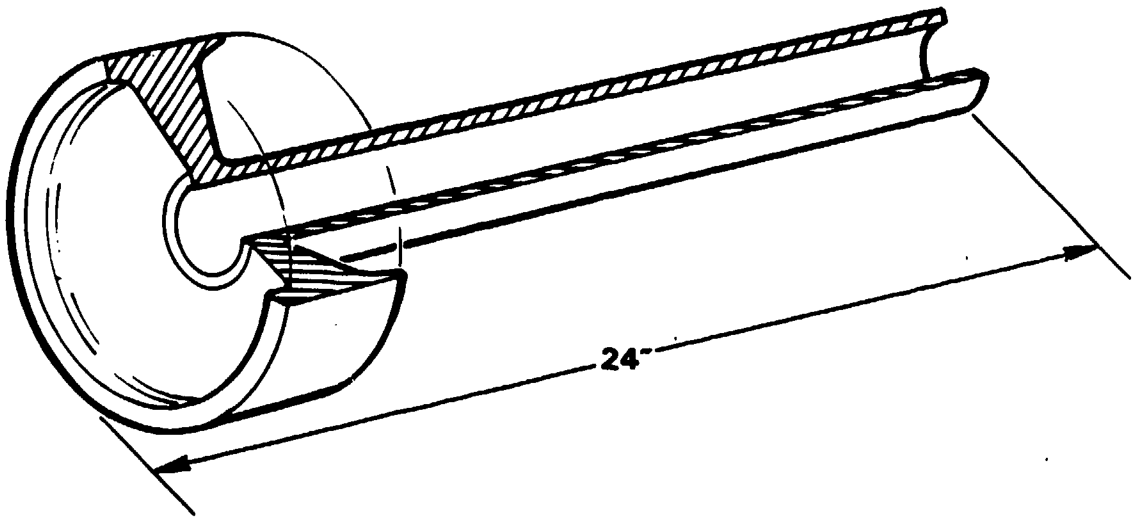
C. Box shapes, pocketed cross sectional "H" shapes, and circular shapes with enclosing ribs.

D. "C" above with thin nonsymmetrical protrusions.

<u>Note</u>: For design proportions and/or tolerances that are closer than the standard design practices or are difficult to classify in the above classifications, consult value or producibility function in company utilizing MC/DG.

FORGING CLASSIFICATION

"A" CONVENTIONAL FORGING



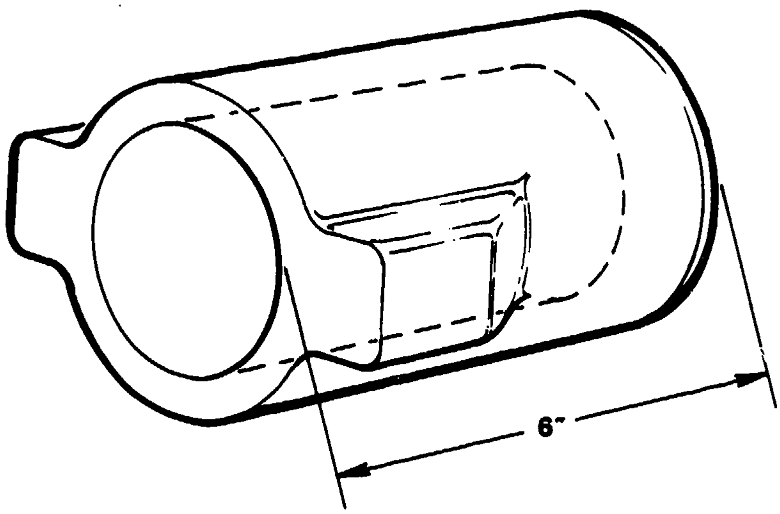


FIGURE 4.6-14

FORGING CLASSIFICATION

"A" CONVENTIONAL FORGING

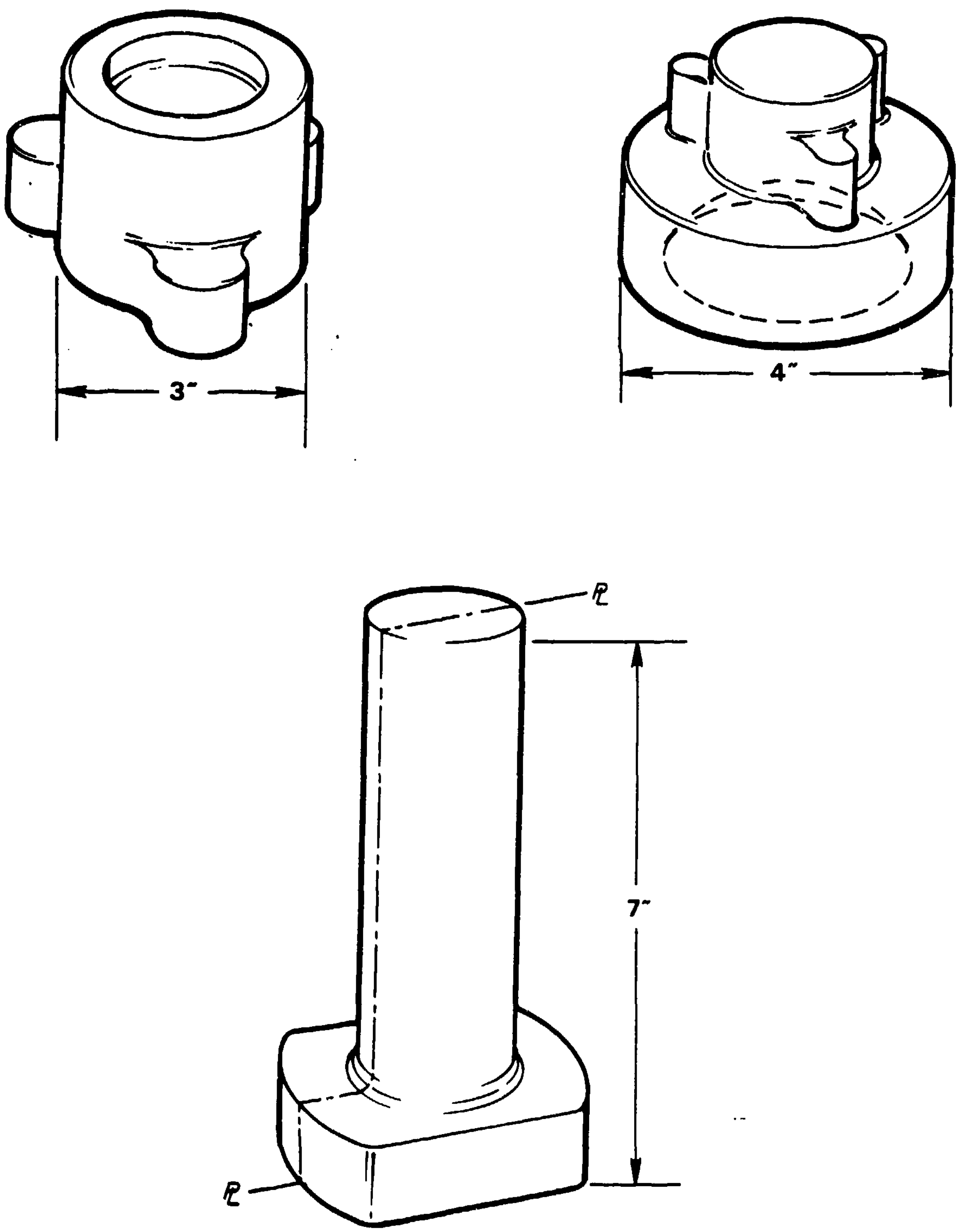


FIGURE 4.6-15

FORGING CLASSIFICATION

"A" PRECISION FORGING

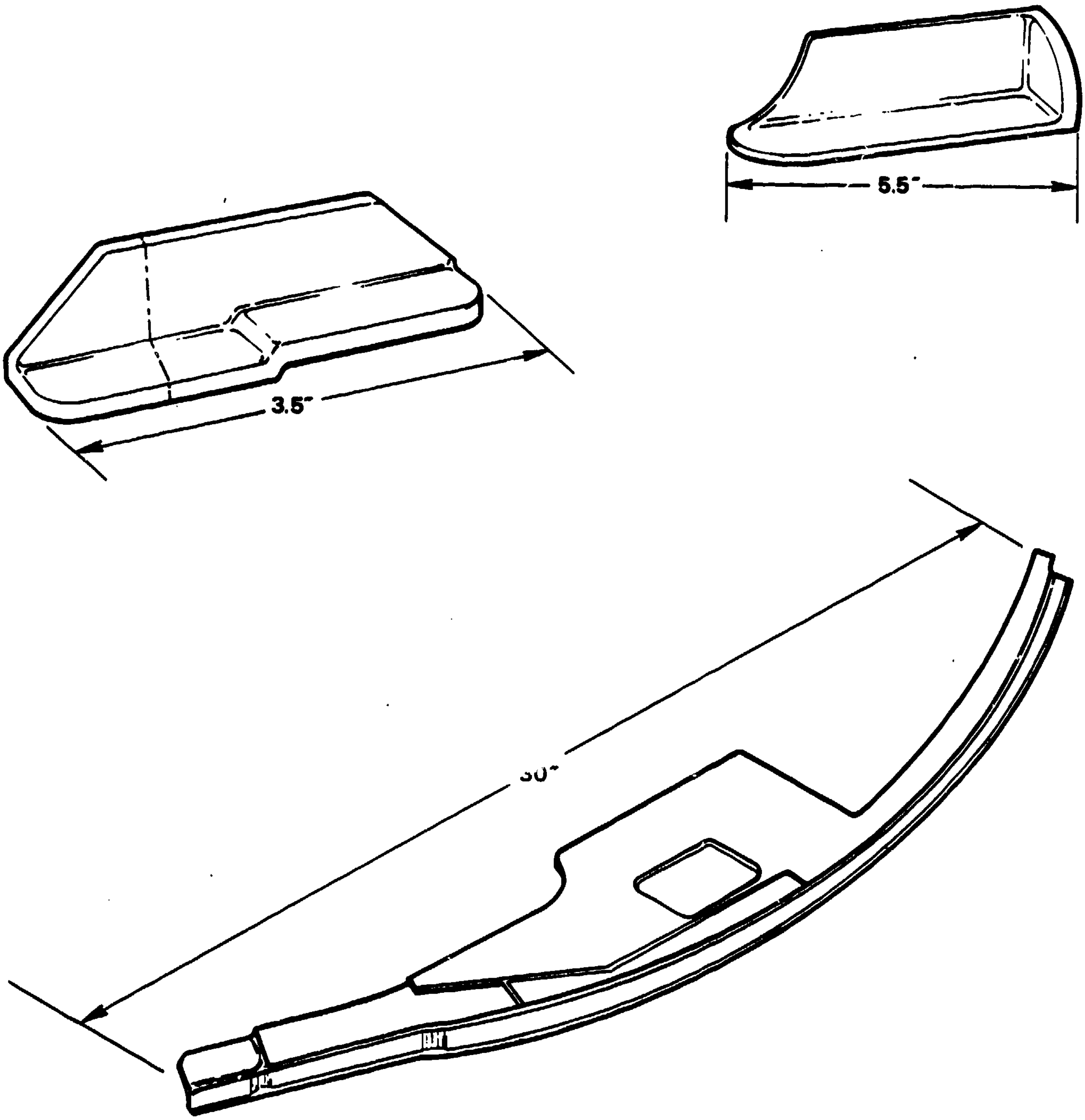


FIGURE 4.6-16

FORGING CLASSIFICATION
"B" PRECISION FORGING

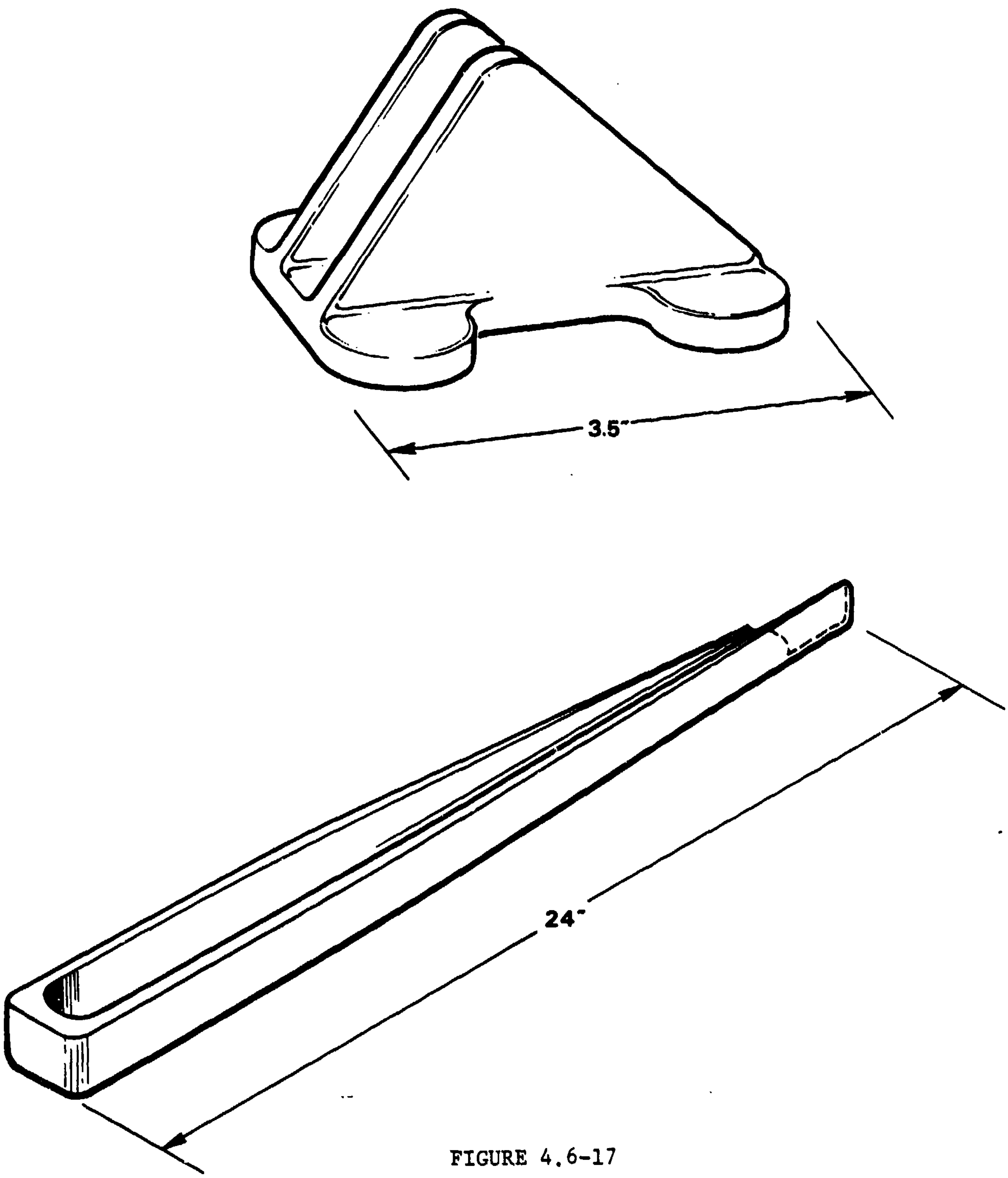


FIGURE 4.6-17

FORGING CLASSIFICATION
"B" CONVENTIONAL FORGING

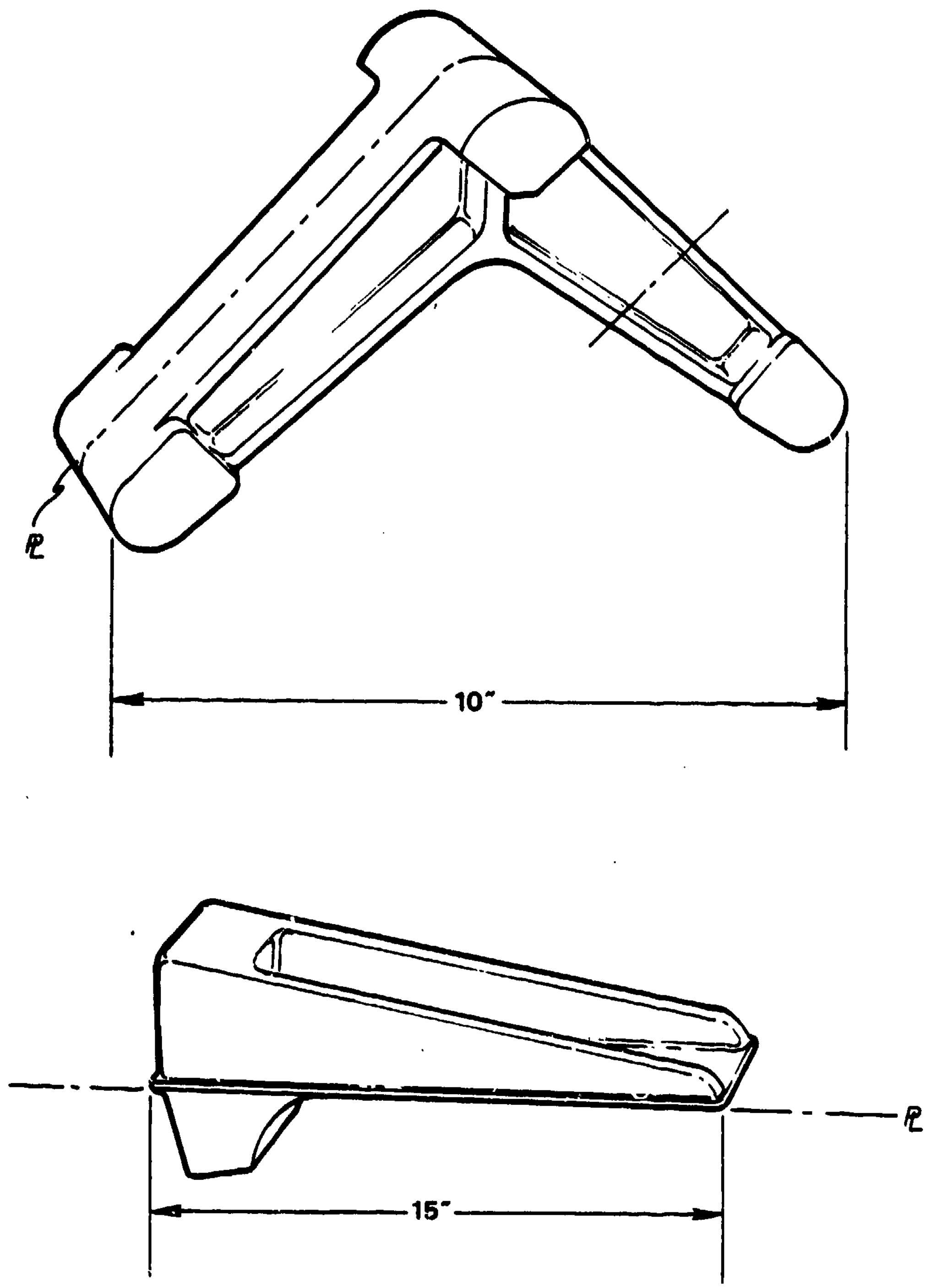
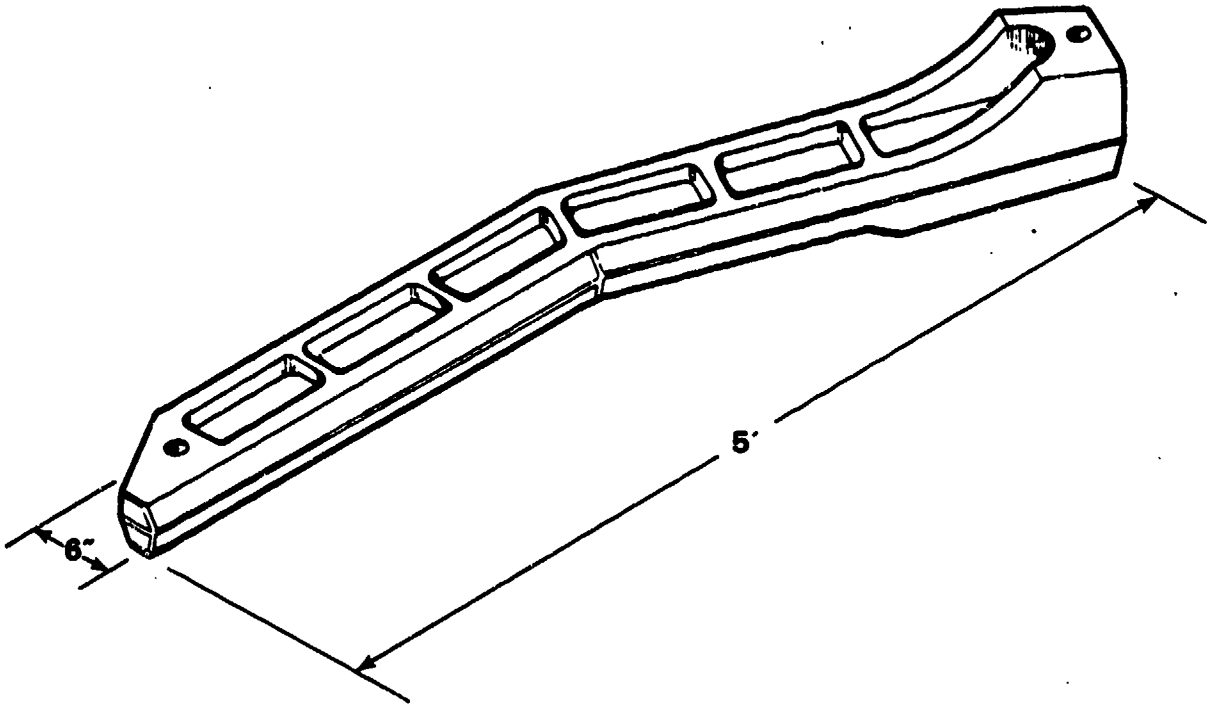


FIGURE 4.6-18

FORGING CLASSIFICATION
"B" CONVENTIONAL FORGING



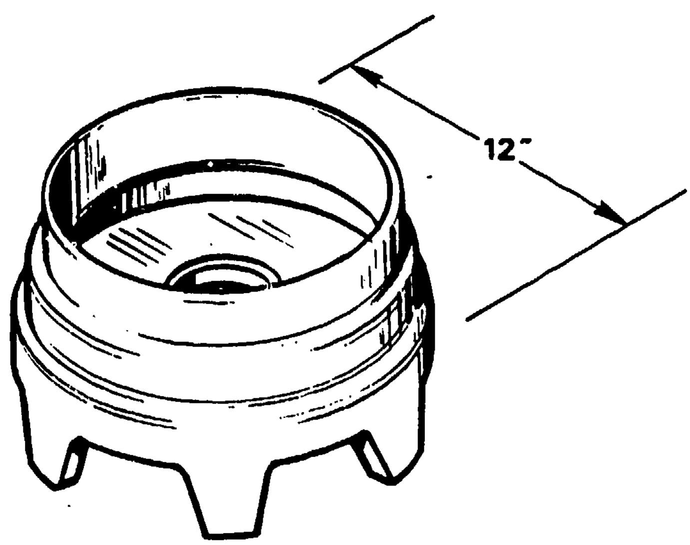
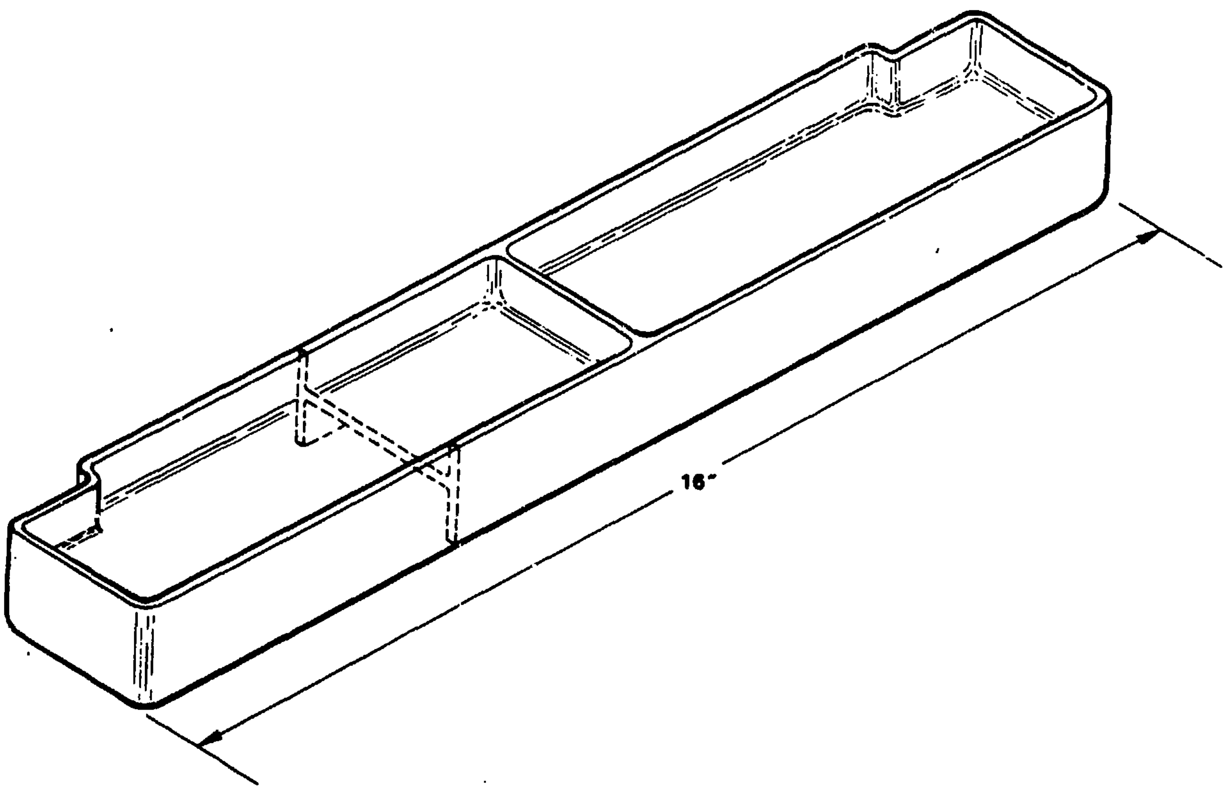


FIGURE 4.6-19

FORGING CLASSIFICATION
"C" PRECISION FORGING



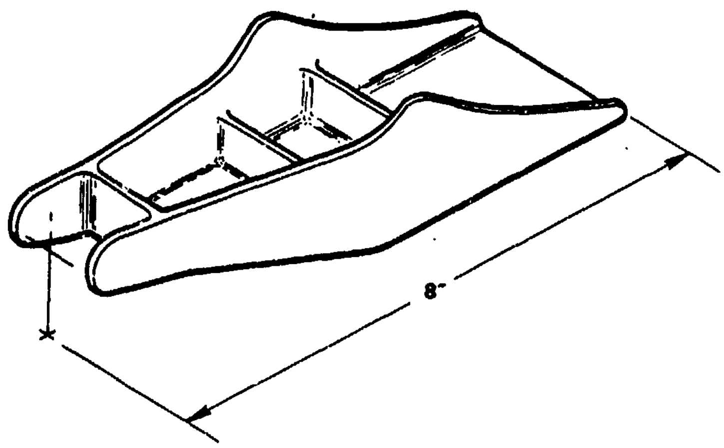
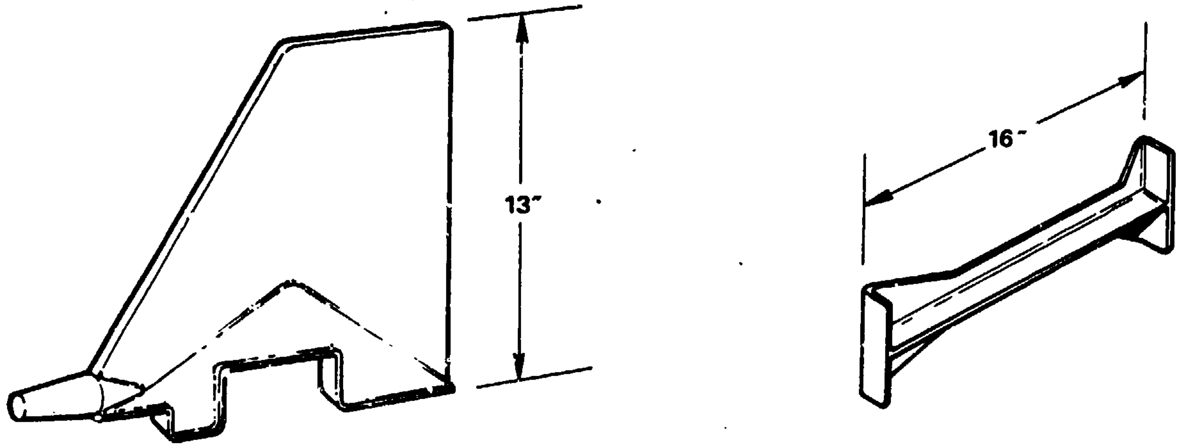
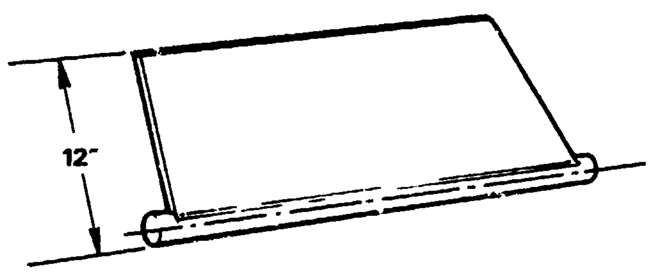


FIGURE 4.6-20

FORGING CLASSIFICATION

"C" CONVENTIONAL FORGING





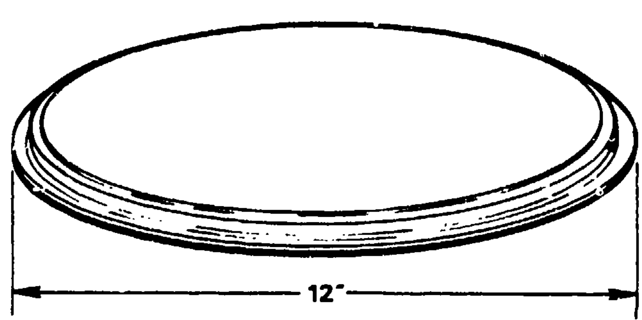


FIGURE 4.6-21

FORGING CLASSIFICATION

"C" PRECISION FORGING

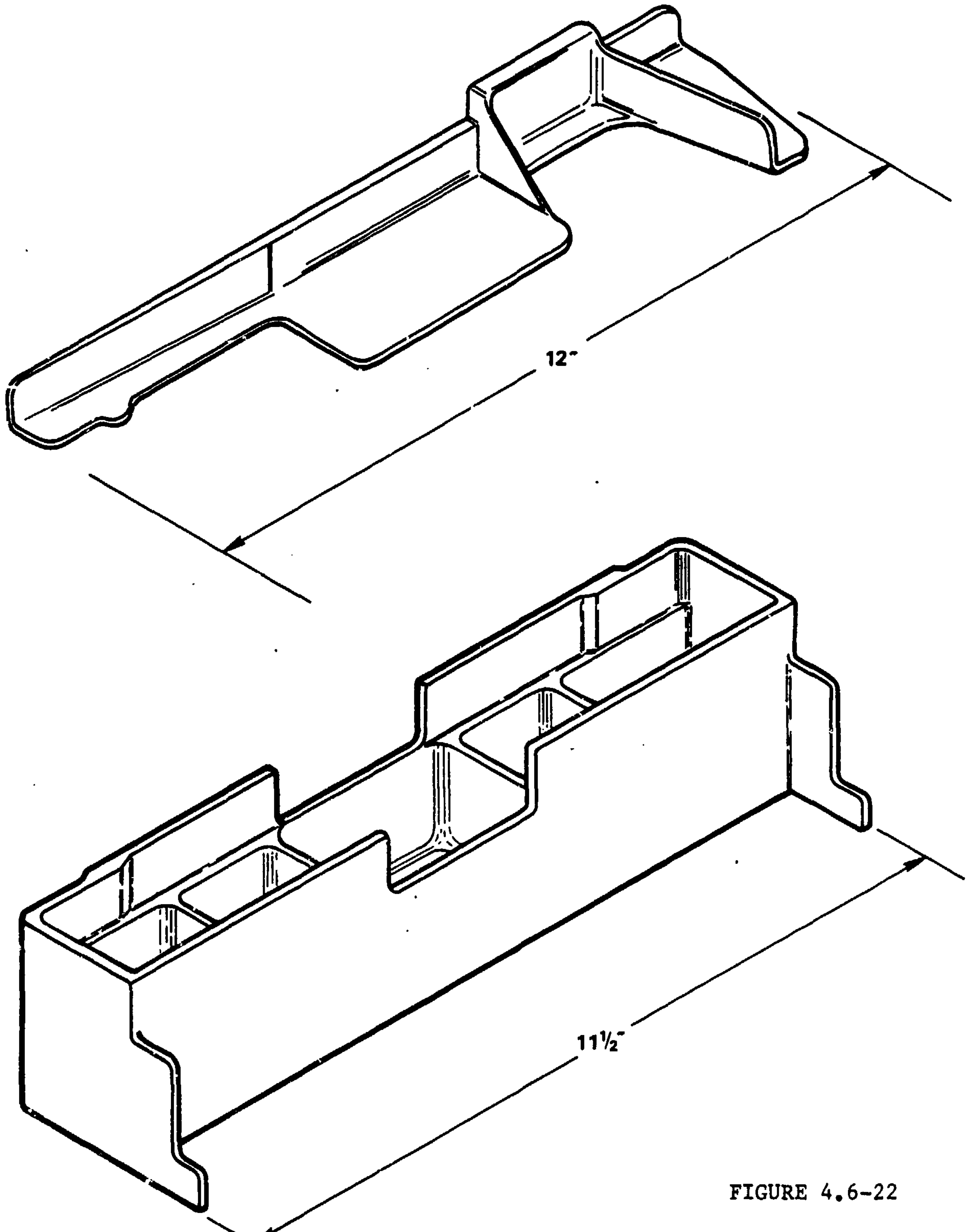
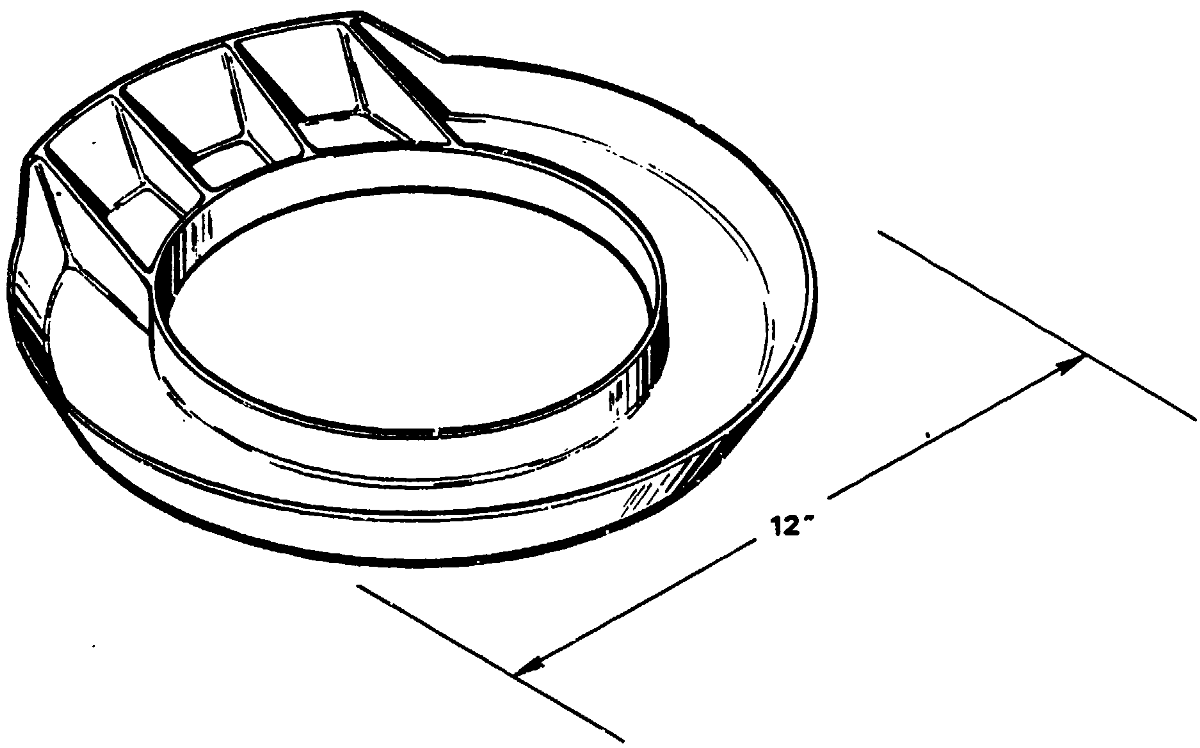


FIGURE 4.6-22

FORGING CLASSIFICATION
"D" PRECISION FORGING



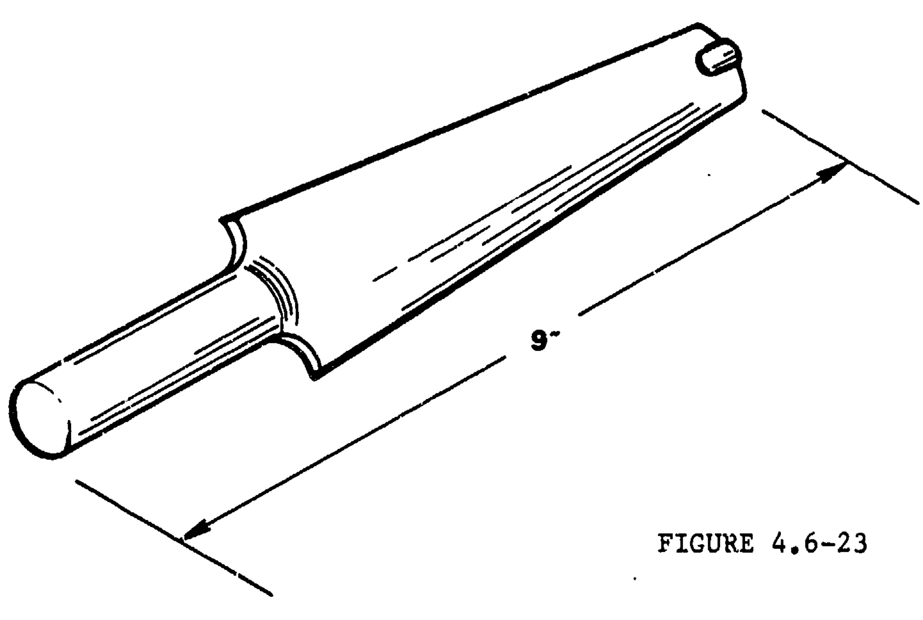


FIGURE 4.6-23

FORGING CLASSIFICATION

"D" CONVENTIONAL FORGING

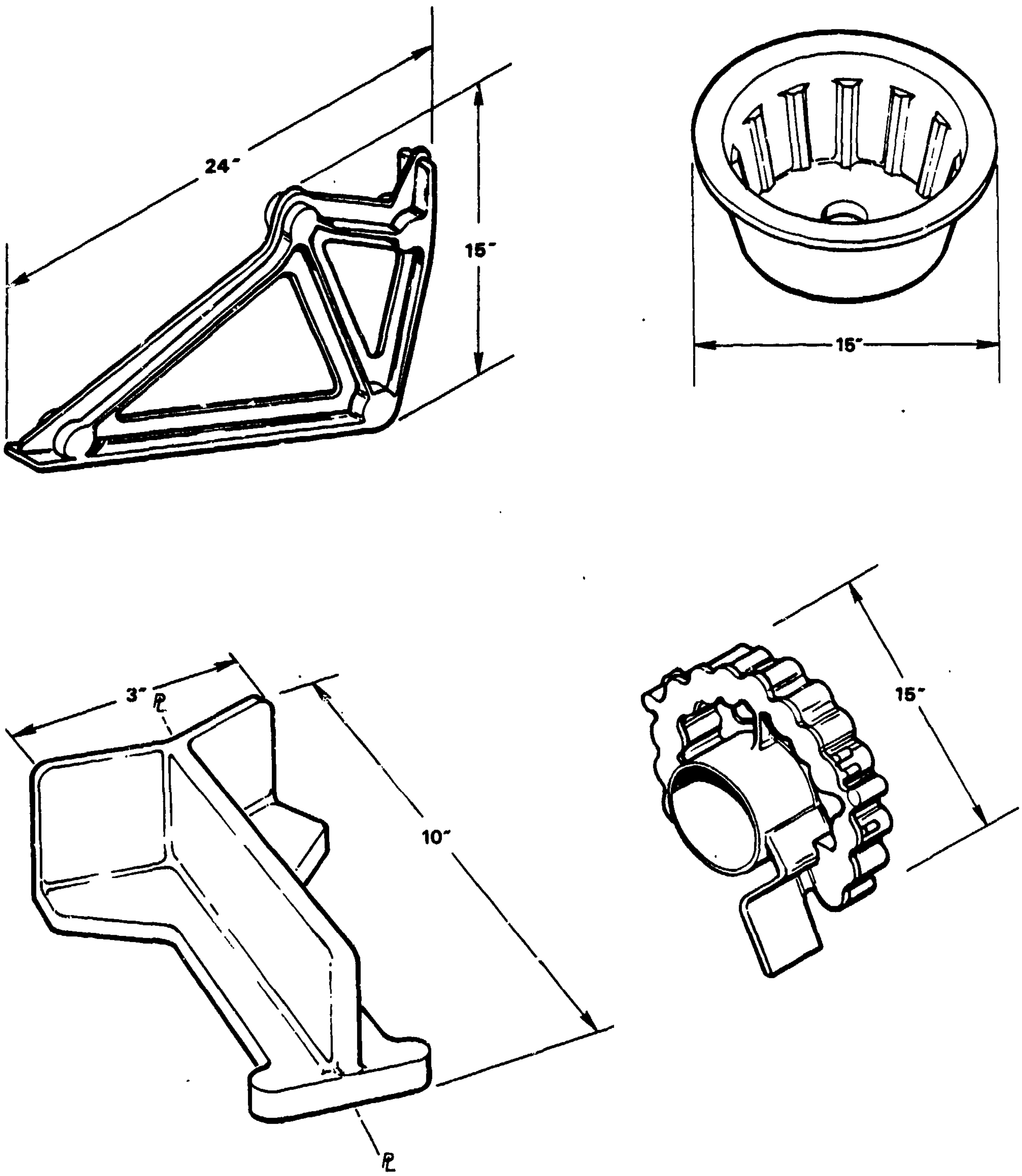
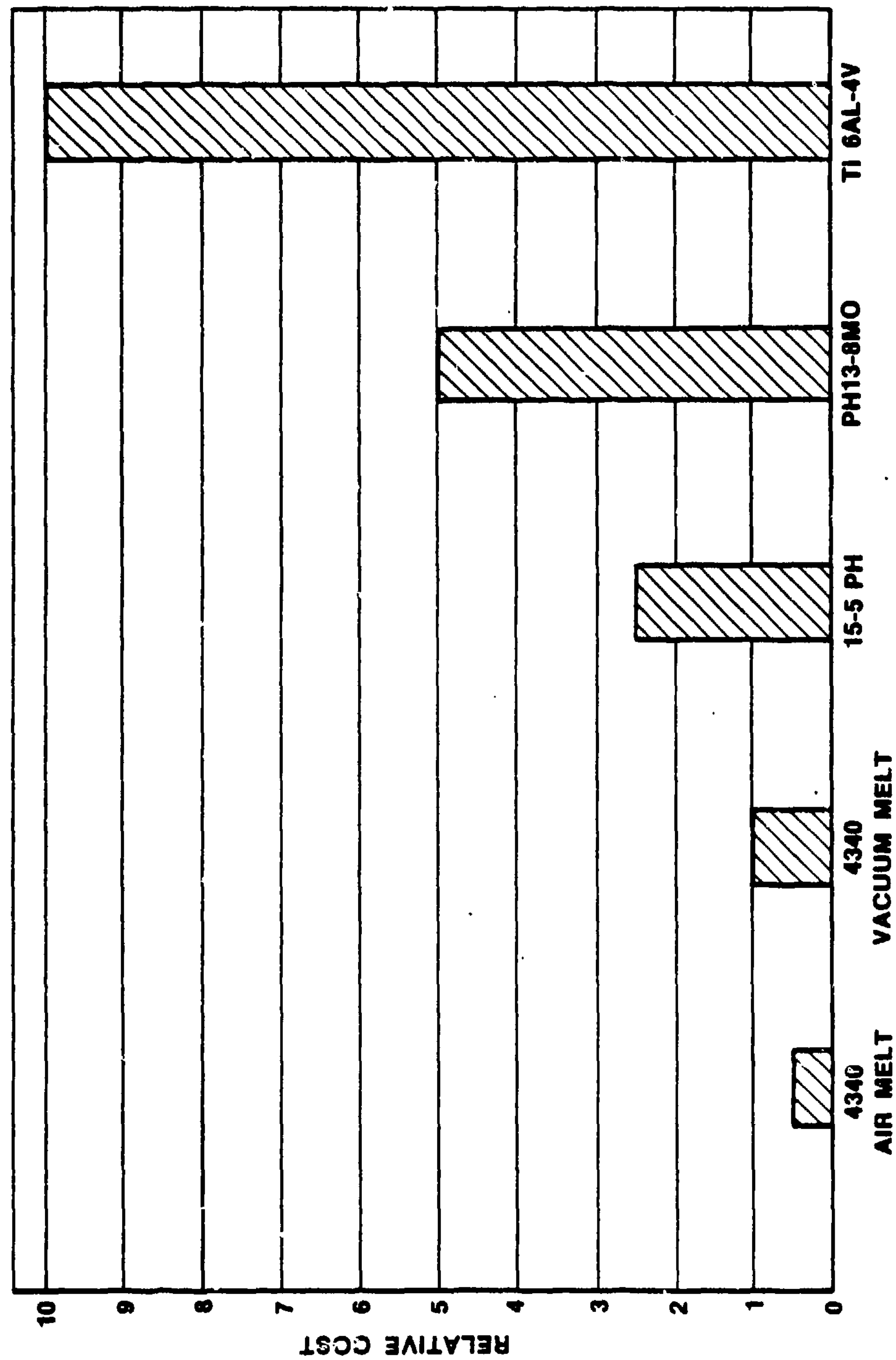


FIGURE 4.6-24

4.6.4 Forging Manufacturing Cost Data

The formats on the following pages provide designer guidance to lowest cost and also enable cost trade-studies to be conducted. As forgings are normally machined, the extent of which is function of the forging type, formats are also included on the cost of machining.

IMPACT OF MATERIAL ON RECURRING COST OF TITANIUM AND STEEL CONVENTIONAL FORGINGS



CDE-FC-I

COST OF CONVENTIONAL VS. BLOCKER FORGINGS

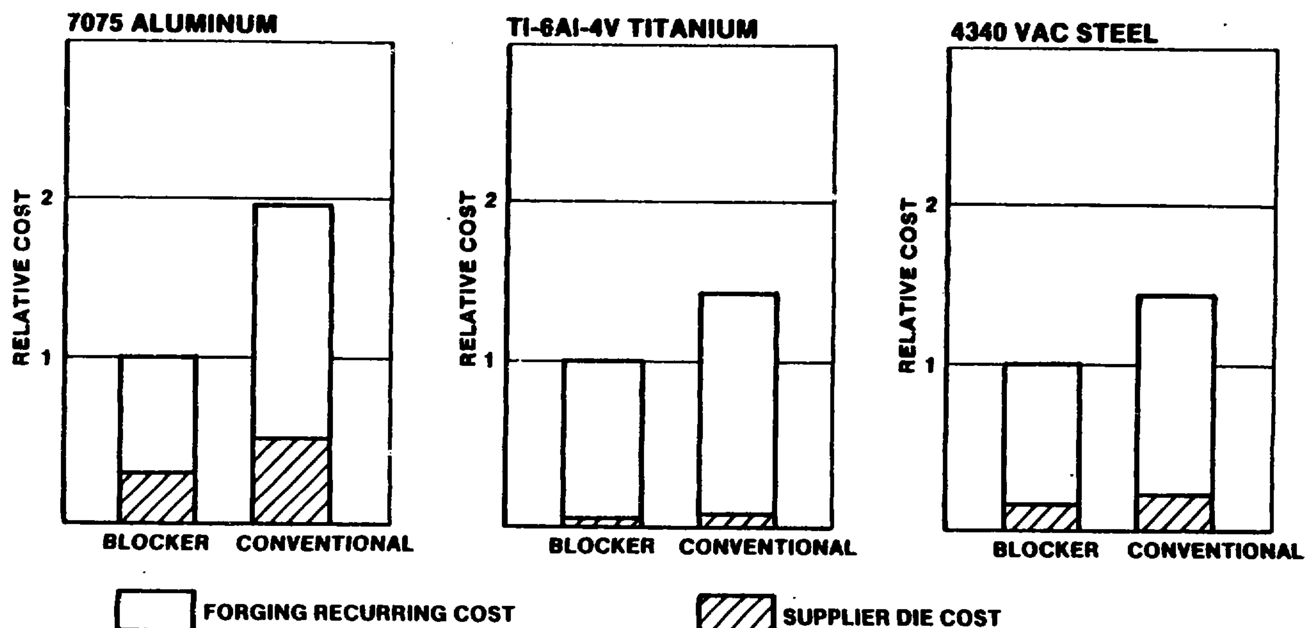
PREMISES

FINISHED PART — VOLUME — 100 CU IN.; PLAN AREA — 170 SQ. IN.; L-36", W-6", H-3"

DESIGN QUANTITY — 200 PARTS; BUY QUANTITY — 50 PARTS

MACHINING OF FORGING TO FINISHED PART NOT INCLUDED

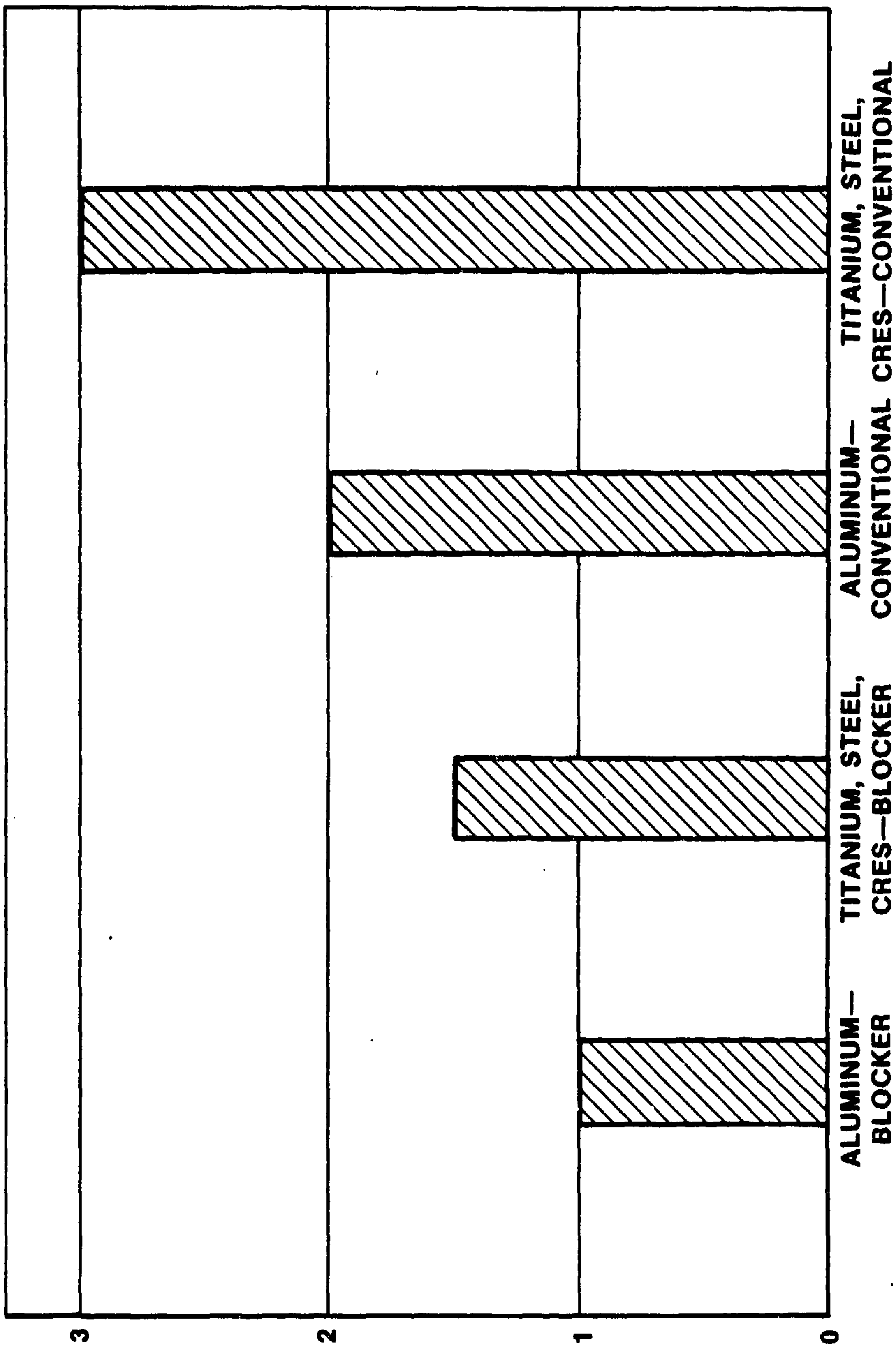
MATERIAL	FINISHED WEIGHT	AS-FORGED CONVENTIONAL	AS-FORGED BLOCKER
7075 ALUMINUM	10 LB.	30 LB.	50 LB.
TI-6AI-4V	16 LB.	80 LB.	112 LB.
4340 VAC STEEL	28 LB.	140 LB.	196 LB.



CDE-FC-II

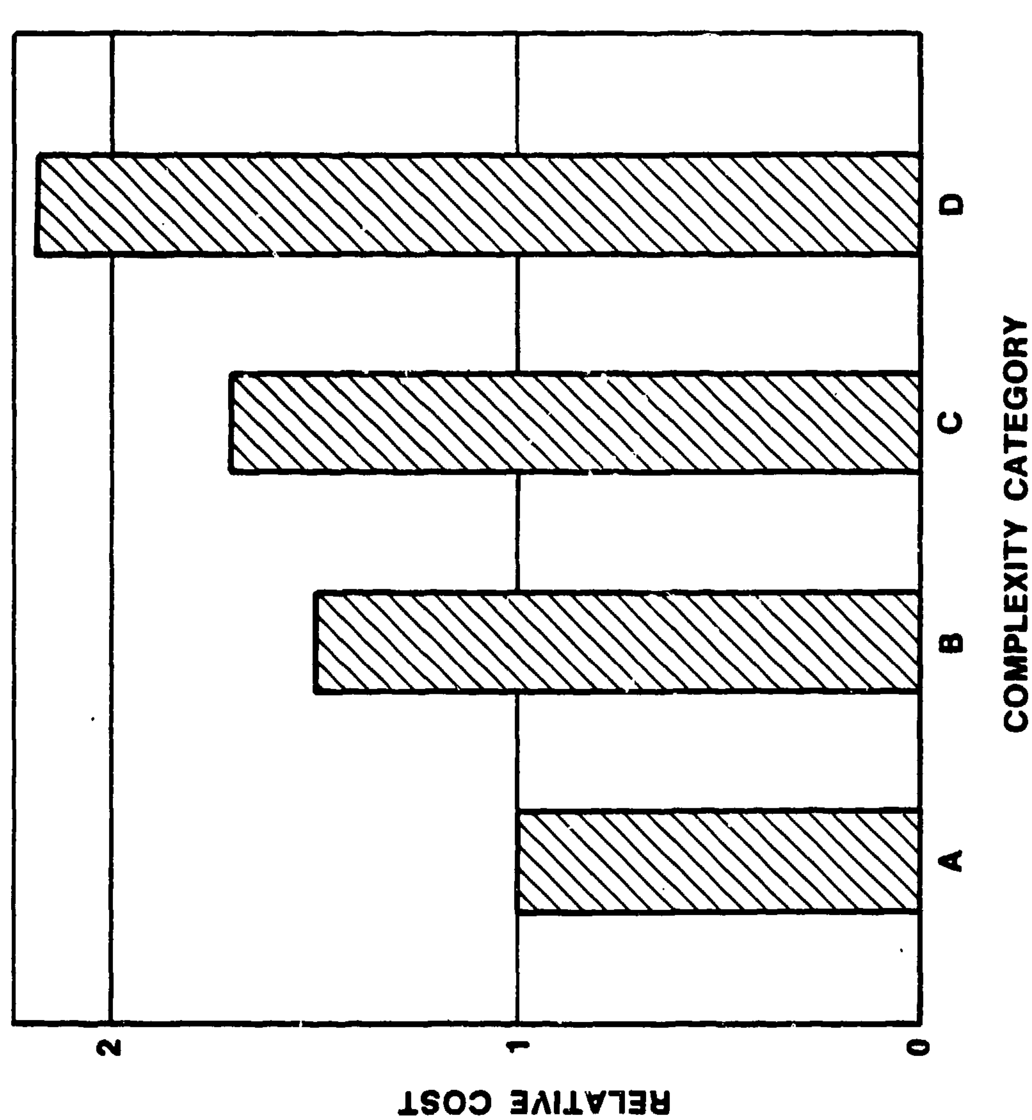
CDE-FC-III

IMPACT OF SUPPLIER TOOLING COST



IMPACT OF COMPLEXITY ON RECURRING COST OF CONVENTIONAL FORGINGS

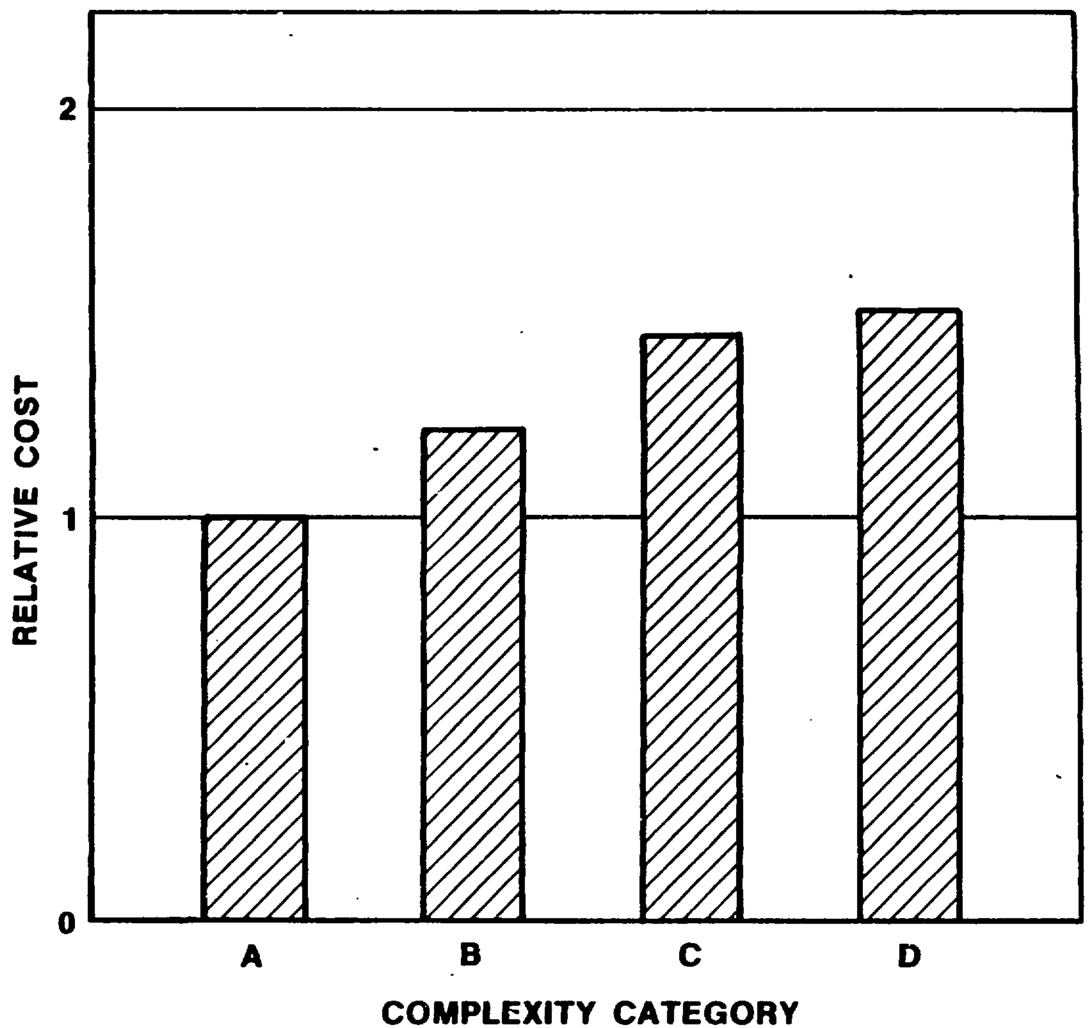
ALUMINUM



CDE-FC-IV

IMPACT OF COMPLEXITY ON RECURRING COST OF CONVENTIONAL FORGINGS

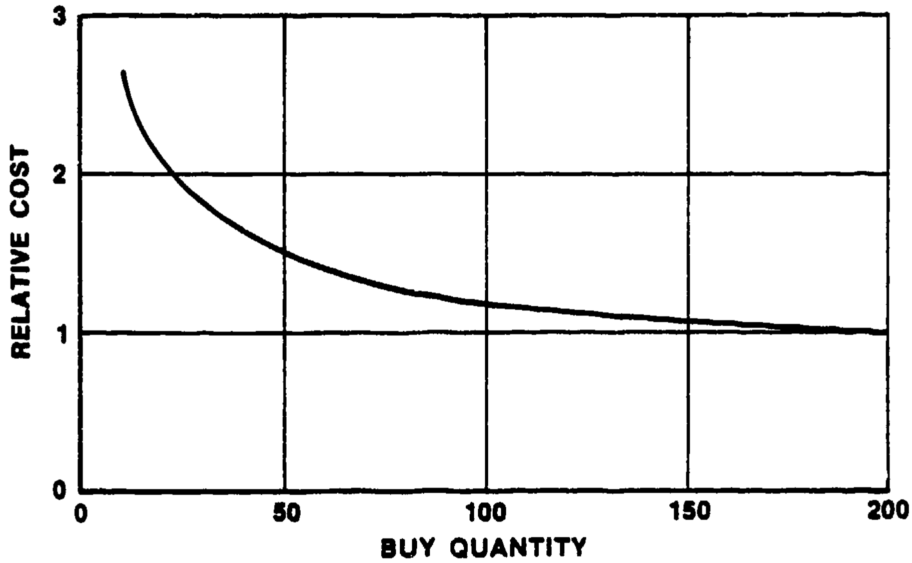
TITANIUM, STEEL & CRES



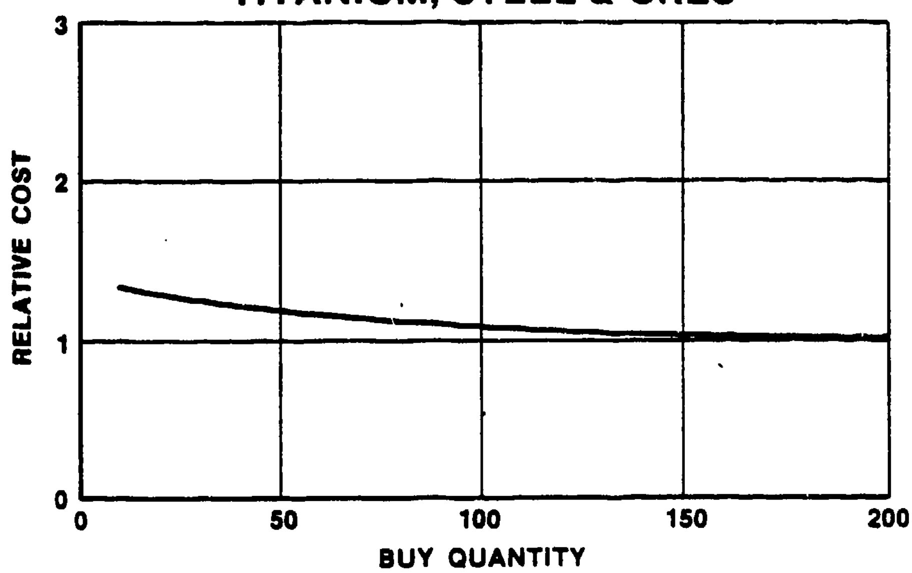
CDE-FC-V

IMPACT OF BUY QUANTITY ON RECURRING COST OF CONVENTIONAL FORGINGS

ALUMINUM

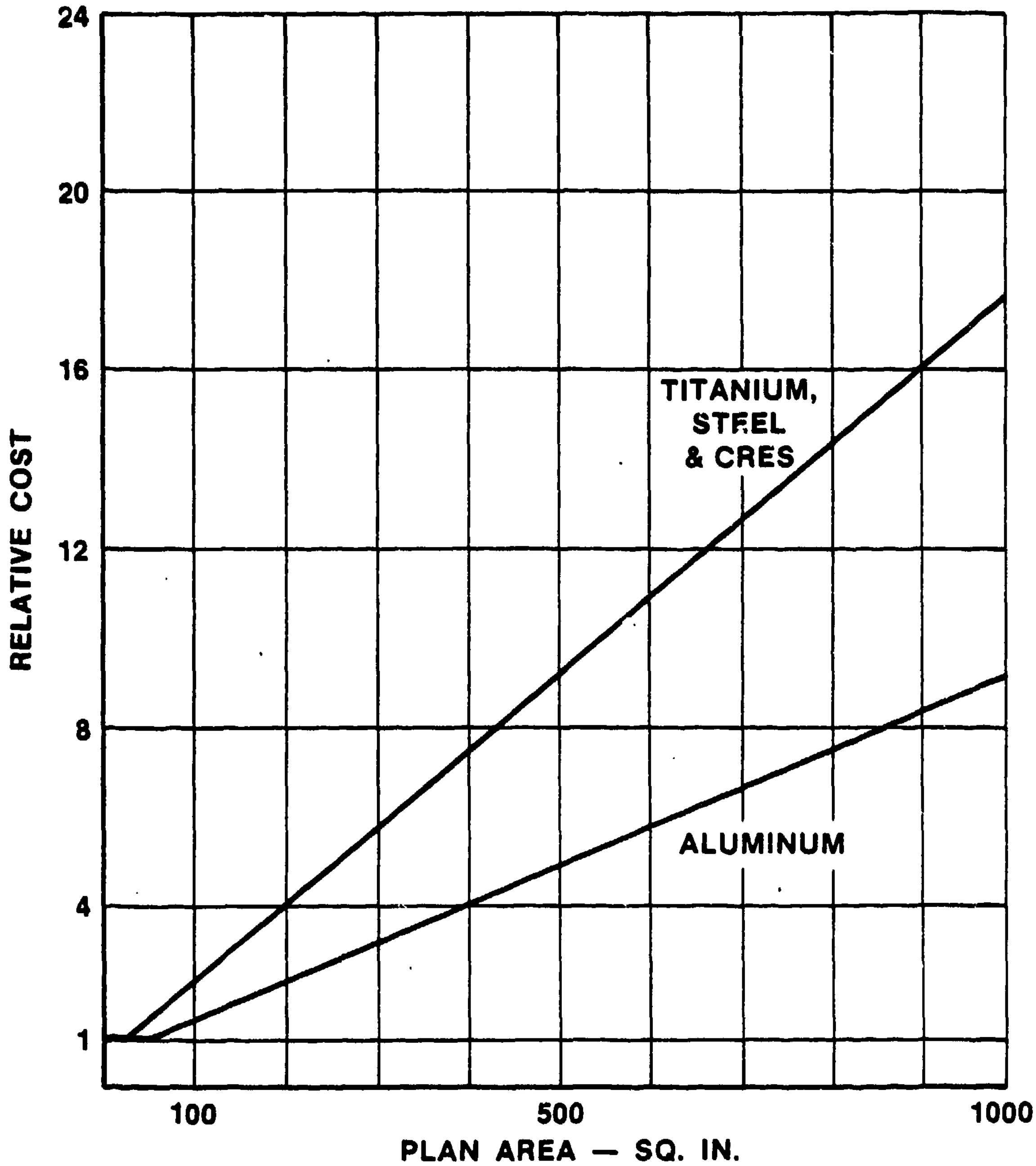


TITANIUM, STEEL & CRES



CDE-FC-VI

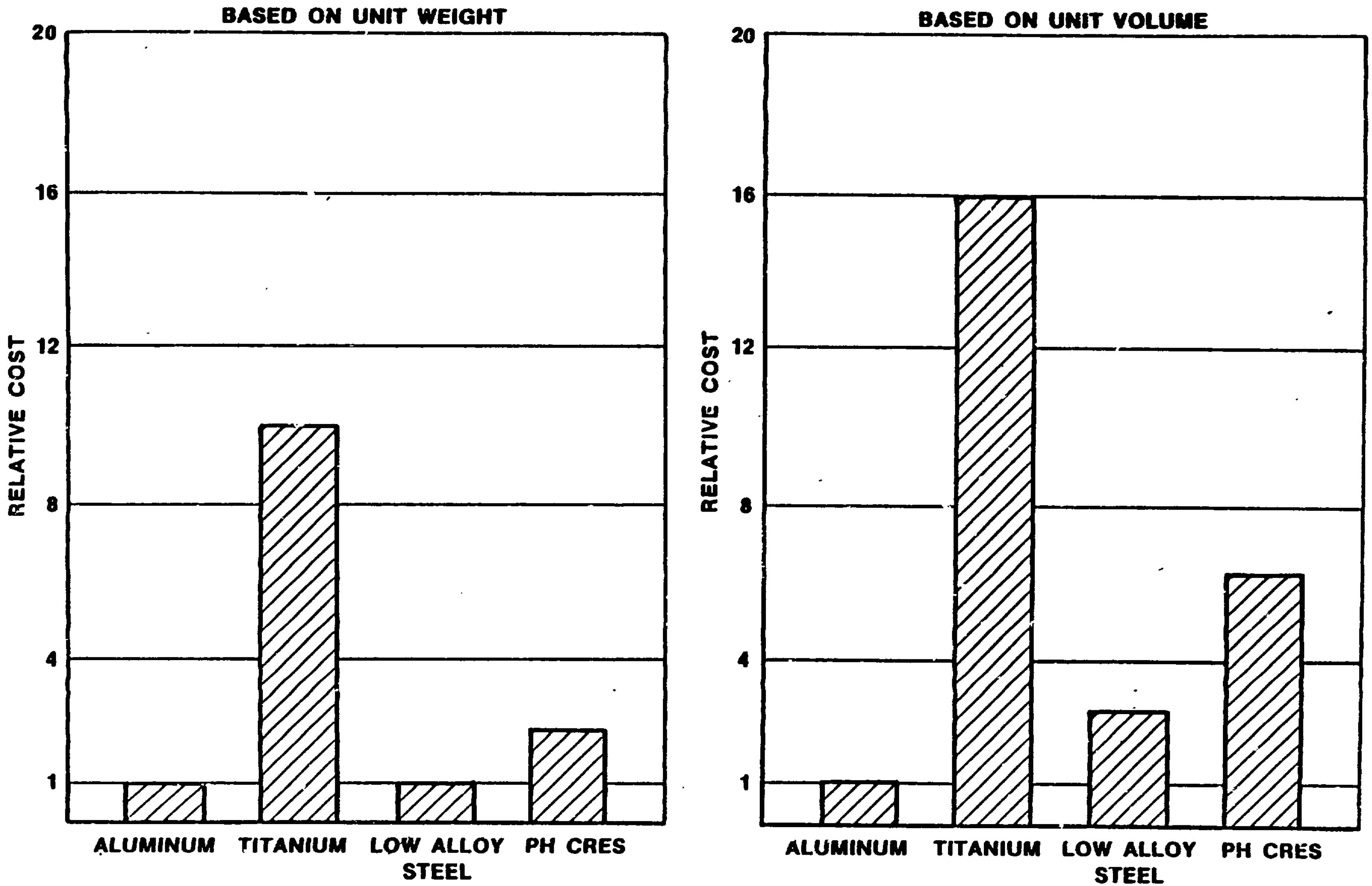
IMPACT OF FORGING SIZE (PLAN AREA) ON THE SETUP COST/PART FOR CONVENTIONAL FORGINGS



NOTE: BASED ON BUY QUANTITY OF 25

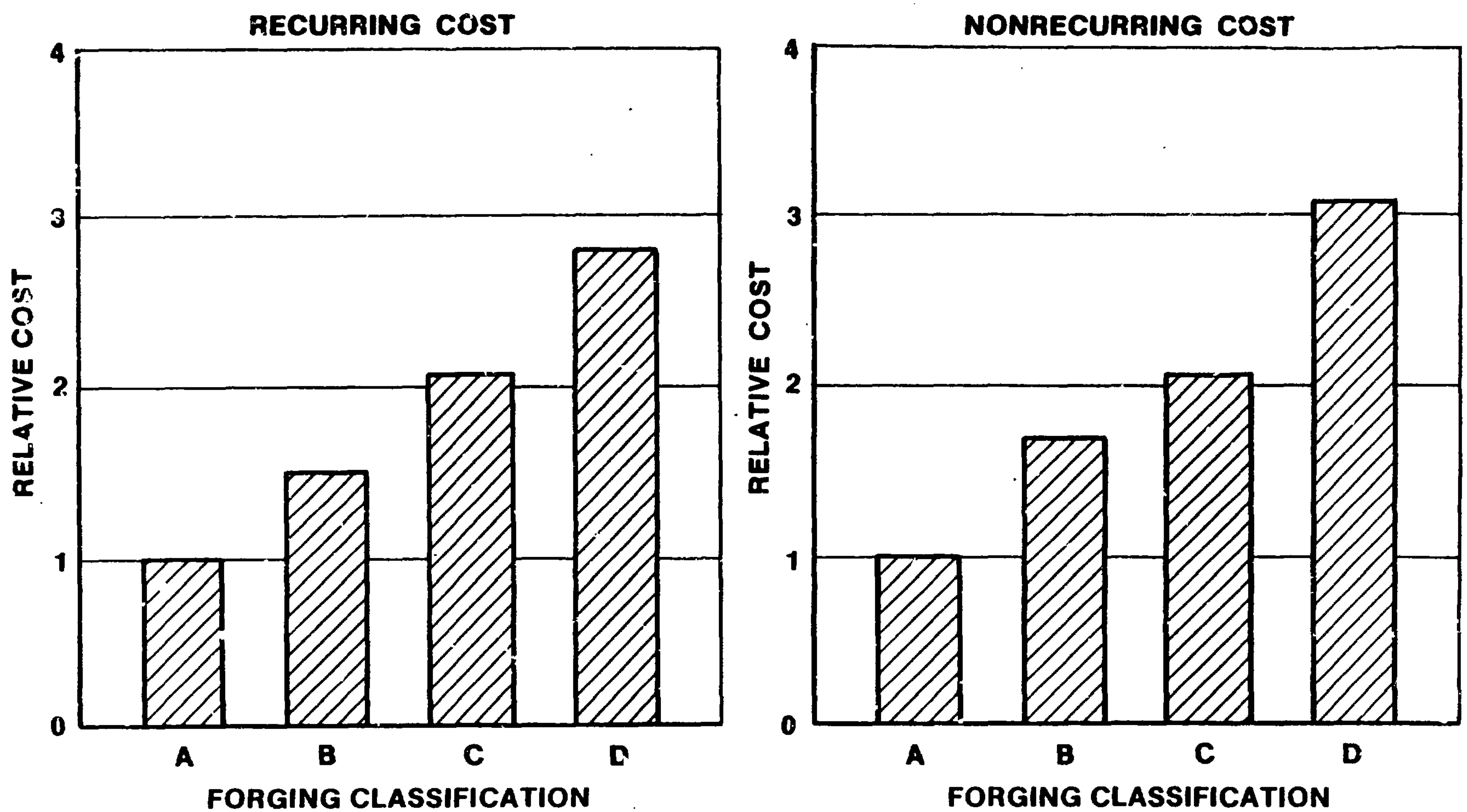
CDE-FC-VII

HAND AND ROLLED RING FORGING EFFECT OF MATERIAL ON COST/POUND OR COST/CUBIC INCH



CDE-FH-I

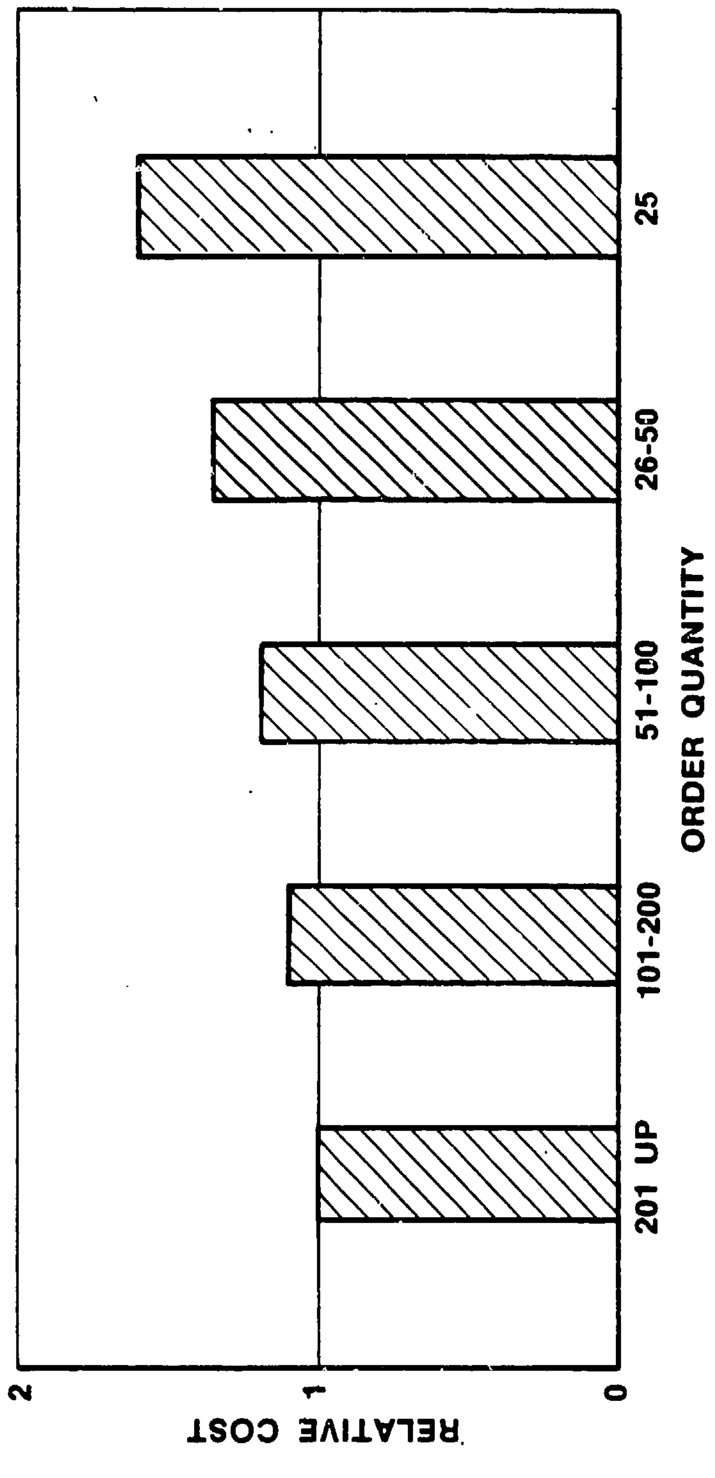
ALUMINUM PRECISION FORGING
EFFECT OF FORGING COMPLEXITY ON RECURRING AND NONRECURRING COSTS



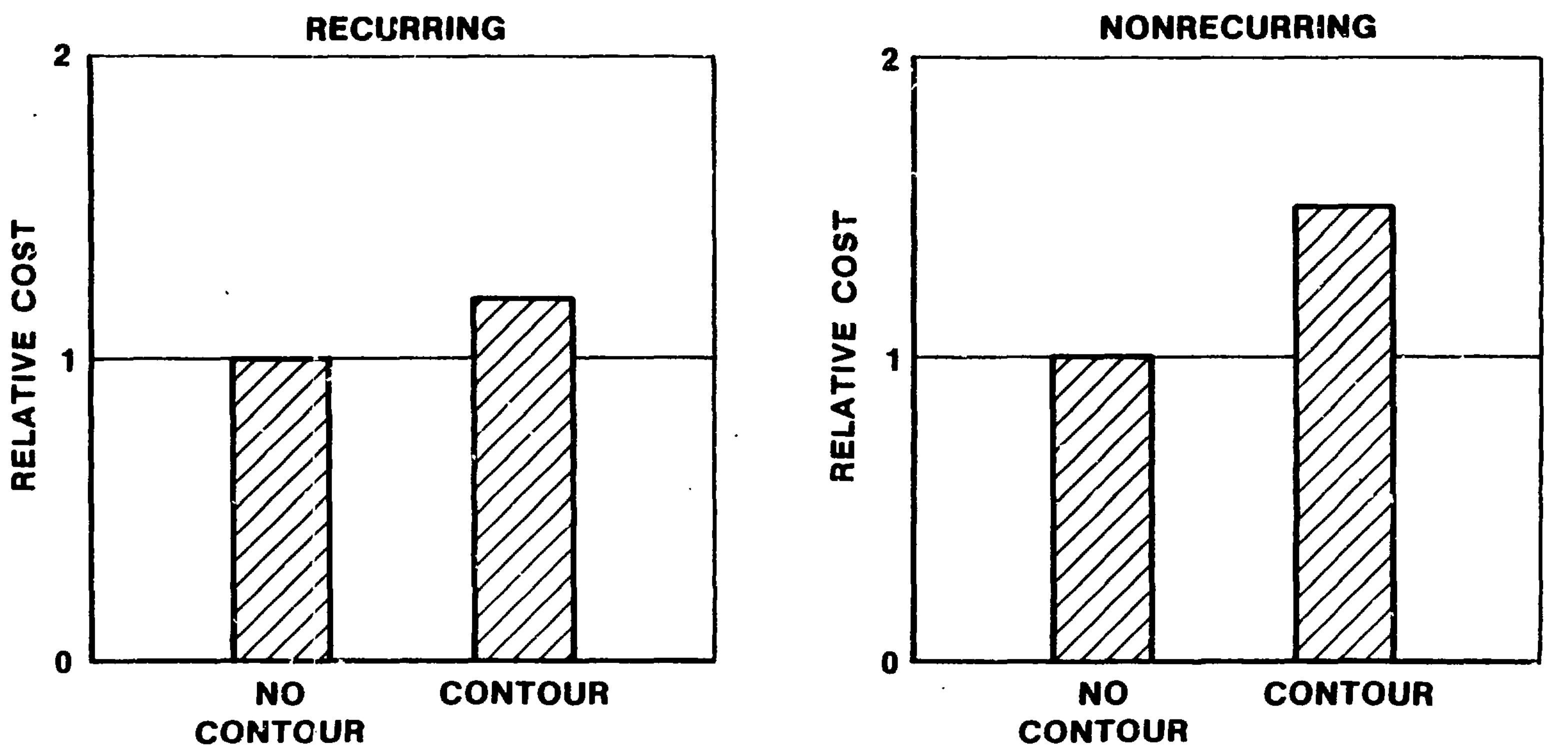
CDE-FP-I

CDE-FP-II

ALUMINUM PRECISION FORGING
EFFECT OF ORDER QUANTITY ON RECURRING COST

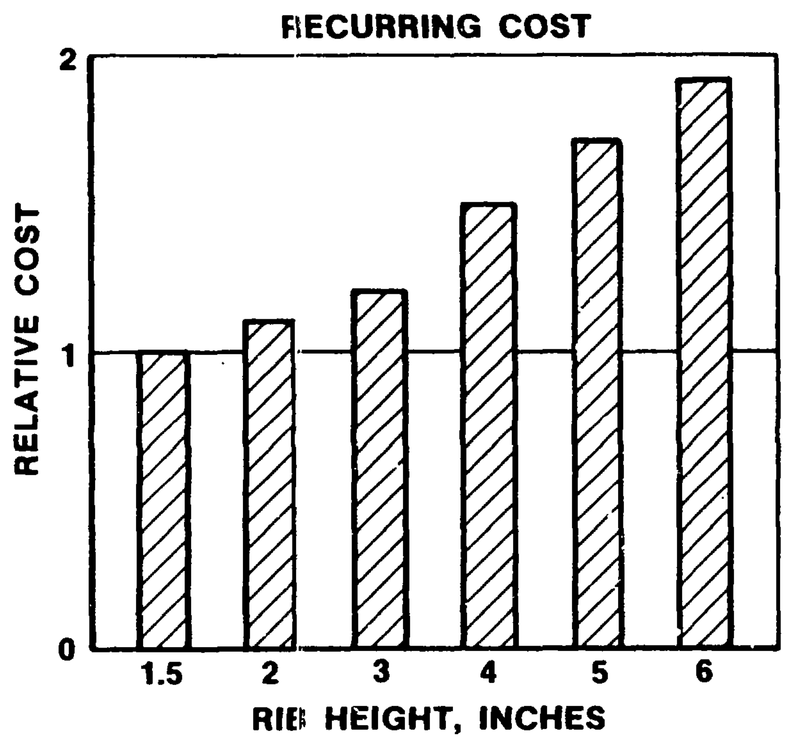


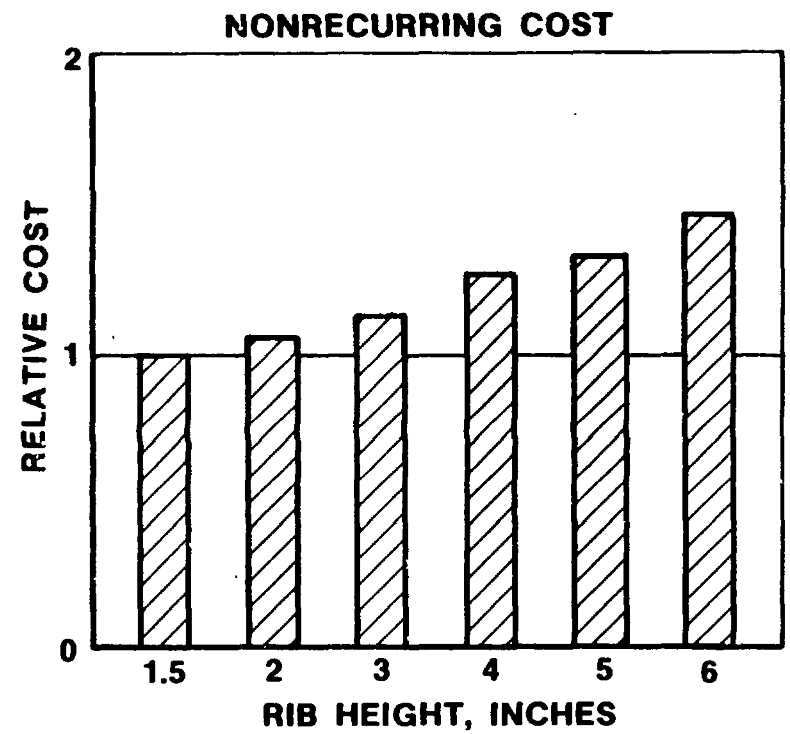
ALUMINUM PRECISION FORGINGS EFFECT OF LOFT CONTOUR ON RECURRING AND NONRECURRING COST



CDE-DICE-FP-I

ALUMINUM PRECISION FORGINGS
EFFECT OF RIB HEIGHT ON RECURRING AND NONRECURRING COST

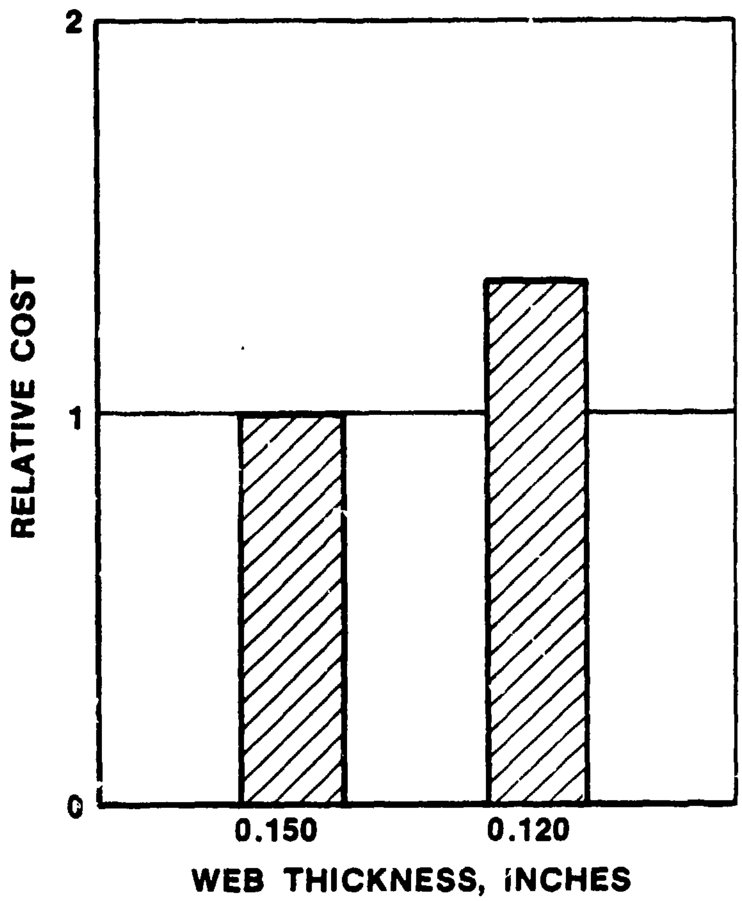




NOTE: BASED ON A 100 SQ. IN. CLASSIFICATION "D" FORGING

CDE-DICE-FP-II

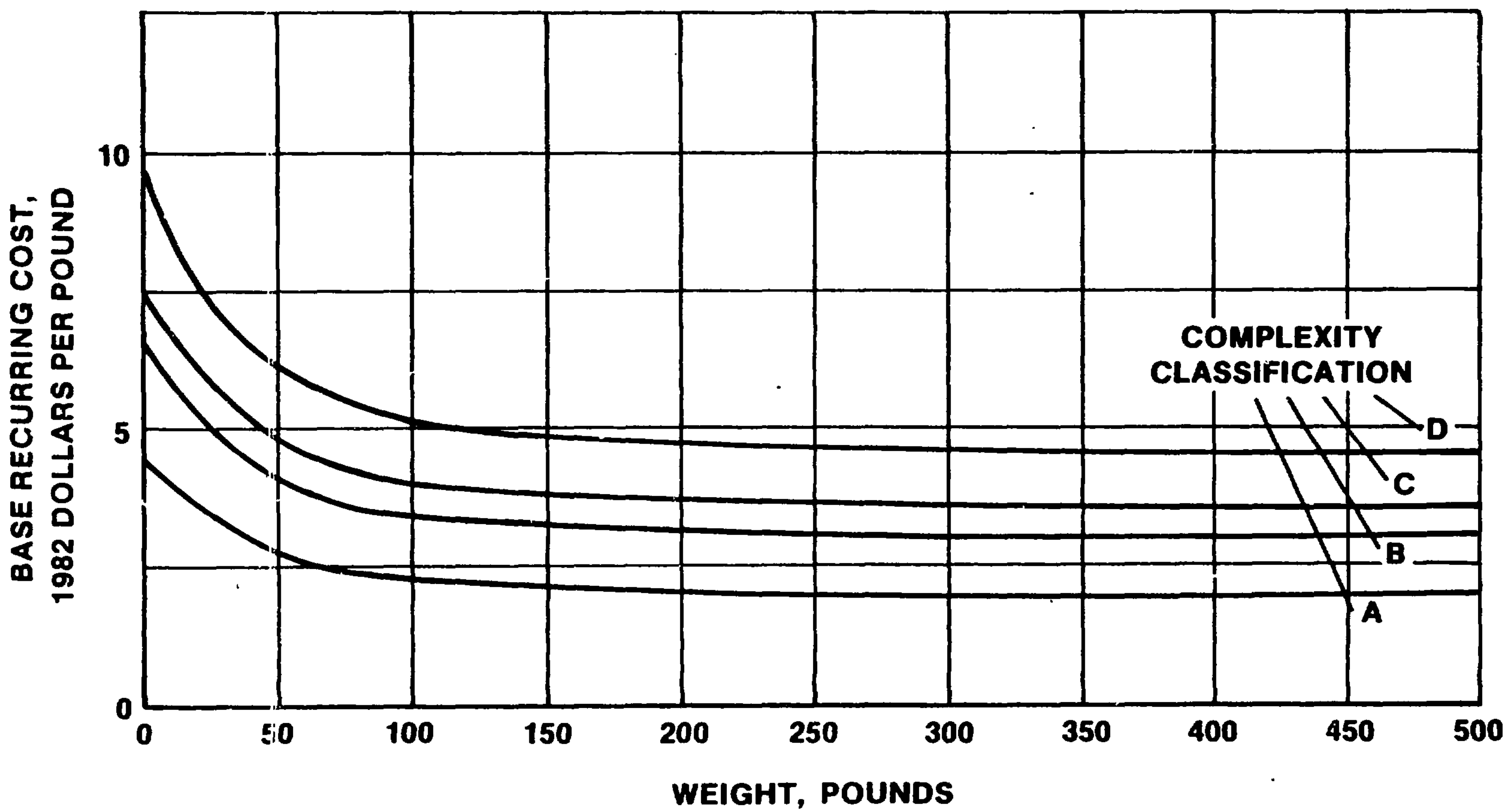
ALUMINUM PRECISION FORGING EFFECT OF FORGED WEB THICKNESS ON RECURRING COST



NOTE: BASED ON A 100 SQ. IN. FORGING

CDE-DICE-FP-III

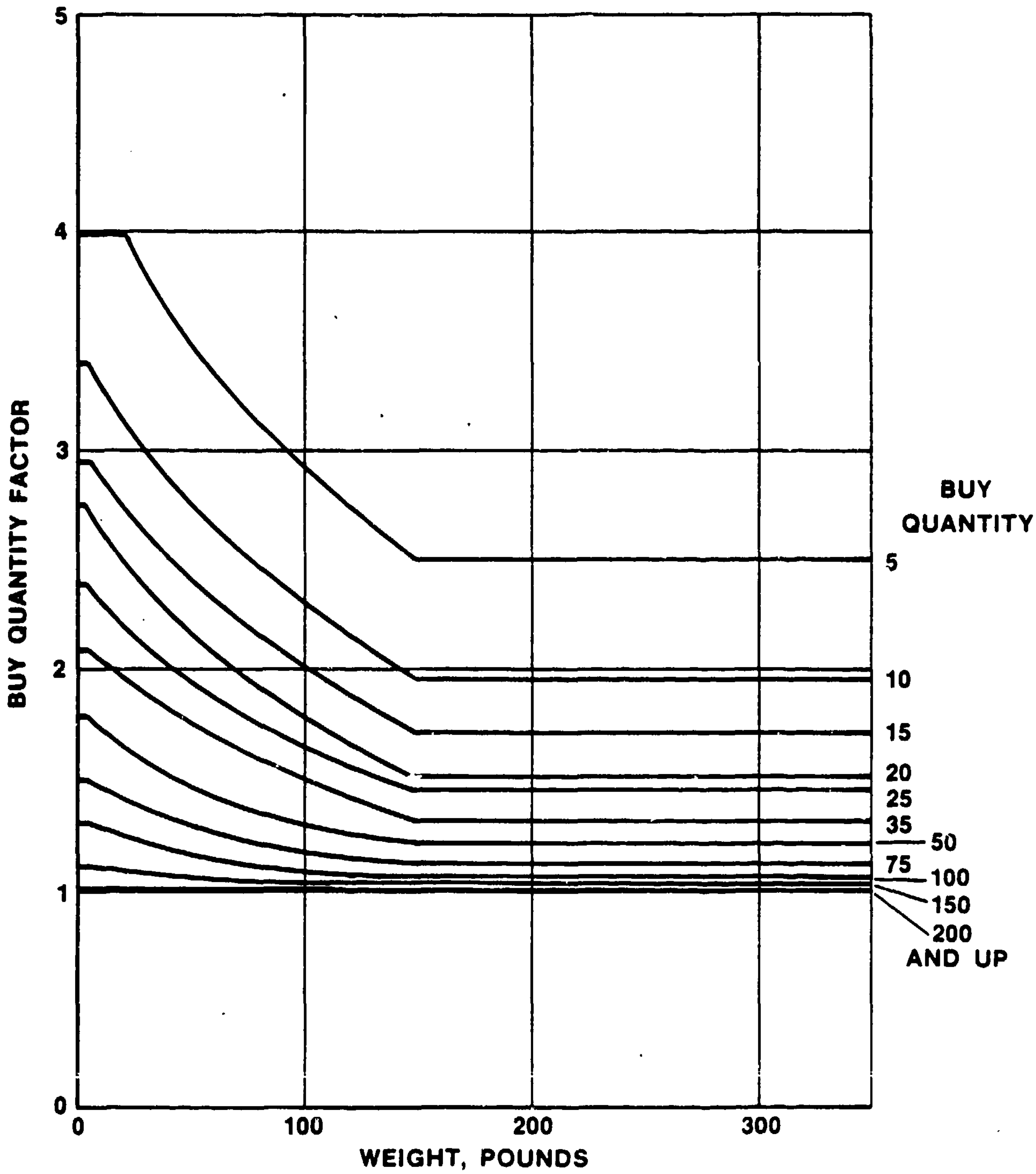
ALUMINUM CONVENTIONAL DIE FORGINGS BASE RECURRING COST



NOTE: BLOCKER FORGING BASE RECURRING COST IS 80 PERCENT OF CLASSIFICATION "A" BASE RECURRING COST.

CED-FC-1

ALUMINUM CONVENTIONAL AND BLOCKER DIE FORGINGS BUY QUANTITY FACTOR



CED-FC-2

ALUMINUM CONVENTIONAL AND BLOCKER DIE FORGINGS SETUP CHARGE PER LOT

SIZE	CHARGE/CLASSIFICATION			
	"A"	"B"	"C"	"D"
50 SQUARE INCHES & UNDER	200	200	250	300
51-100 SQUARE INCHES	350	400	450	500
101-250 SQUARE INCHES	600	700	700	800
251-499 SQUARE INCHES	900	1,000	1,000	1,200
500-999 SQUARE INCHES	2,000	2,400	2,800	3,100
1000-1999 SQUARE INCHES	3,500	3,500	3,700	3,700
2000 SQUARE INCHES & OVER	4,200	4,200	4,200	4,200

NOTE: FOR BLOCKER FORGING, USE SETUP CHARGE PER LOT FOR CLASSIFICATION "A"

CED-FC-3

ALUMINUM CONVENTIONAL AND BLOCKER DIE FORGINGS NONRECURRING TOOLING COST (NRTC)

TO DETERMINE THE NONRECURRING TOOLING COST, UTILIZE THE FOLLOWING FORMULA:

$$[(L + 12) \times (W + 12) \times (T + 14)] \times \text{METHOD FACTOR} \times \text{INFLATION FACTOR} = \text{NRTC}$$

WHERE
L = LENGTH
W = WIDTH
T = THICKNESS

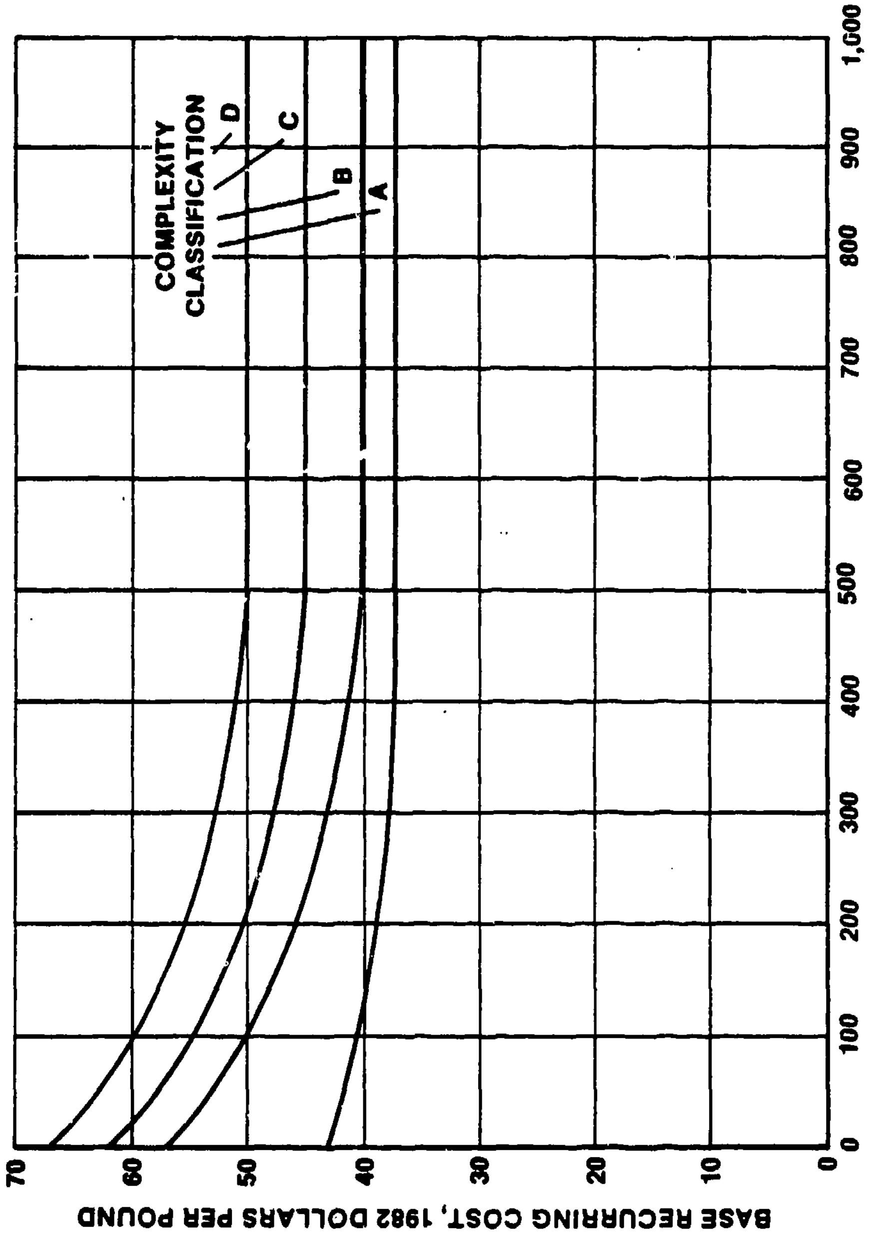
METHOD FACTORS

METHOD	FACTOR
BLOCKER	1
CONVENTIONAL WITH FLATBACK	1
CONVENTIONAL	2

NOTE: INFLATION FACTOR TO BE SUPPLIED BY INDIVIDUAL USER COMPANY.

CED-FC-4

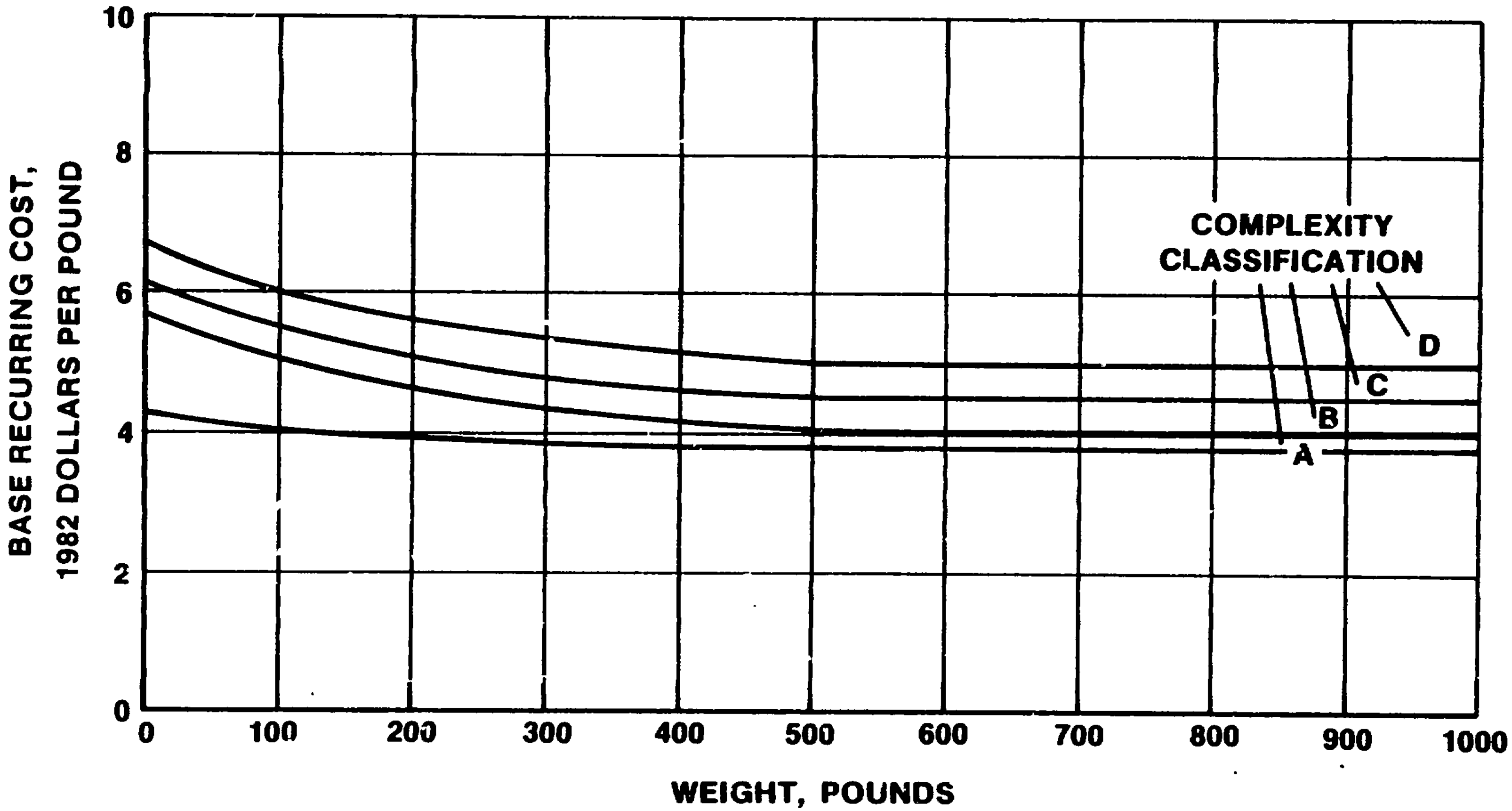
TITANIUM 6AL-4V CONVENTIONAL DIE FORGING BASE RECURRING COST



NOTE: BLOCKER FORGING BASE RECURRING COST IS 80 PERCENT OF CLASSIFICATION "A" BASE RECURRING COST.

CED-FC-5

4340 STEEL CONVENTIONAL DIE FORGING BASE RECURRING COST

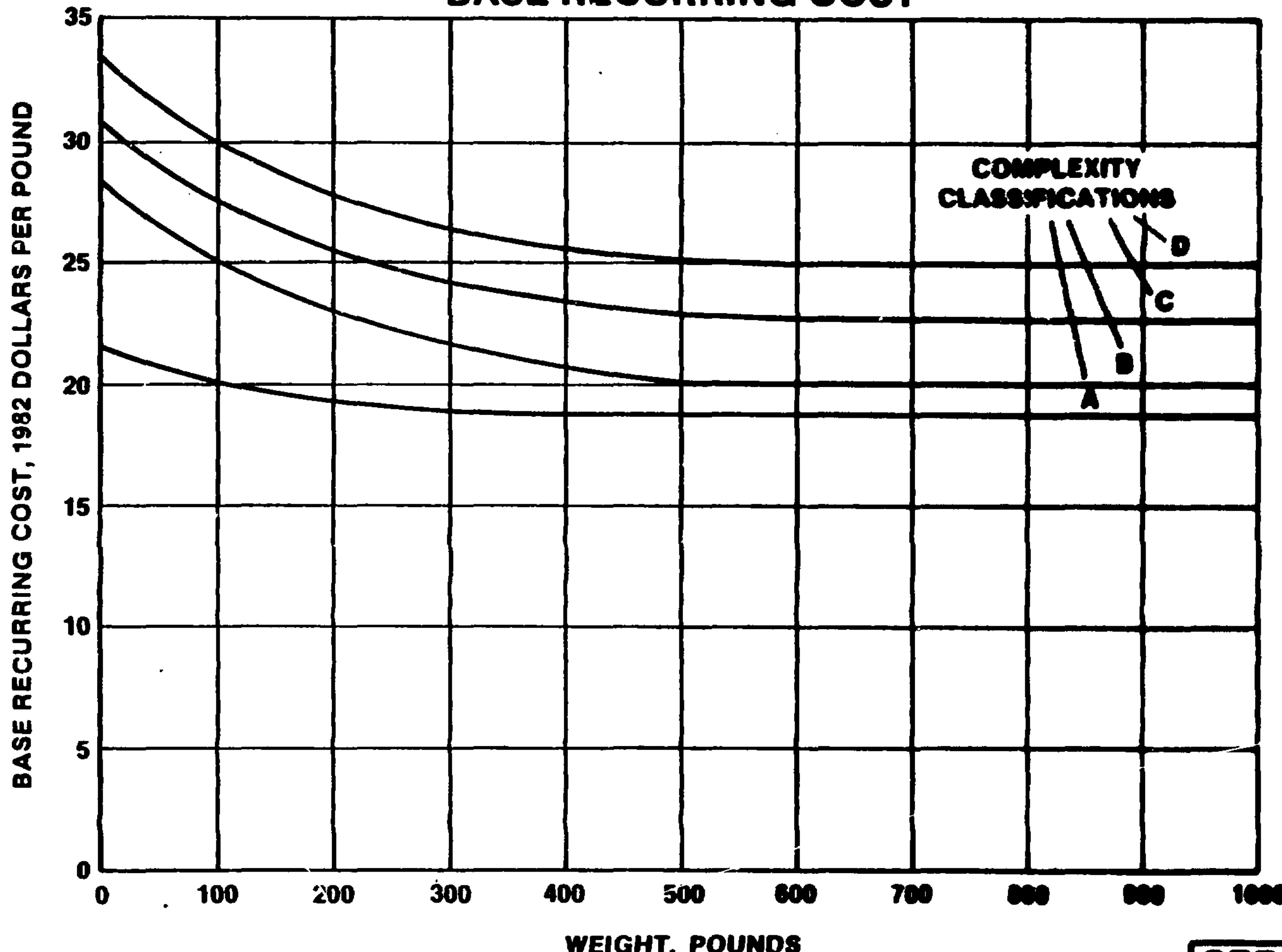


NOTE: THE CURVES REPRESENT VACUUM ARC MELT (VAR), FOR AIR MELT USE 50 PERCENT OF CURVES.

BLOCKER FORGING BASE RECURRING COST IS 80 PERCENT OF CLASSIFICATION "A" BASE RECURRING COST.

CED-FC-6

PH13-8MO CRES CONVENTIONAL DIE FORGING BASE RECURRING COST



CED-FC-7

NOTE: USE 50 PERCENT OF THE ABOVE CURVES FOR 15-5PH FORGING COSTS

BLOCKER FORGING BASE COST IS 80 PERCENT OF CLASSIFICATION "A" BASE RECURRING COST.

TITANIUM, STEEL AND CRES CONVENTIONAL/BLOCKER DIE FORGING BUY QUANTITY

QUANTITY	FACTOR
201	1.0
101-200	1.1
51-100	1.2
26-50	1.25
10-25	1.35

THE LISTED FACTORS ARE TO BE APPLIFD TO TITANIUM, STEEL AND CRES DIE FORGINGS BASED UPON THE BUY QUANTITY.

FOR EXTREMELY LARGE FORGINGS OVER 500 POUNDS, CONSULT DESIGN PRODUCIBILITY.

CED-FC-8

TITANIUM, STEEL AND CRES CONVENTIONAL AND BLOCKER DIE FORGING SETUP CHARGE PER LOT

SIZE	CHARGE/CLASSIFICATION			
	"A"	"B"	"C"	"D"
25 SQUARE INCHES & UNDER	200	200	250	300
26-50 SQUARE INCHES	350	400	450	500
51-125 SQUARE INCHES	600	700	700	800
126-250 SQUARE INCHES	900	1,000	1,000	1,200
251-500 SQUARE INCHES	2,000	2,400	2,800	3,100
500-1000 SQUARE INCHES	3,500	3,500	3,700	3,700
1000 SQUARE INCHES & OVER	4,200	4,200	4,200	4,200

NOTE: FOR BLOCKER FORGINGS, USE CLASSIFICATION "A" SETUP CHARGE PER LOT.

CED-FC-9

TITANIUM, STEEL AND CRES CONVENTIONAL AND BLOCKER DIE FORGINGS NONRECURRING TOOLING COST (NRTC)

TO DETERMINE THE NONRECURRING TOOLING COST, UTILIZE THE FOLLOWING FORMULA:

$$[(L + 12) \times (W + 12) \times (T + 14)] \times \text{METHOD FACTOR} \times \text{INFLATION FACTOR} = \text{NRTC}$$

WHERE
L = LENGTH
W = WIDTH
T = THICKNESS

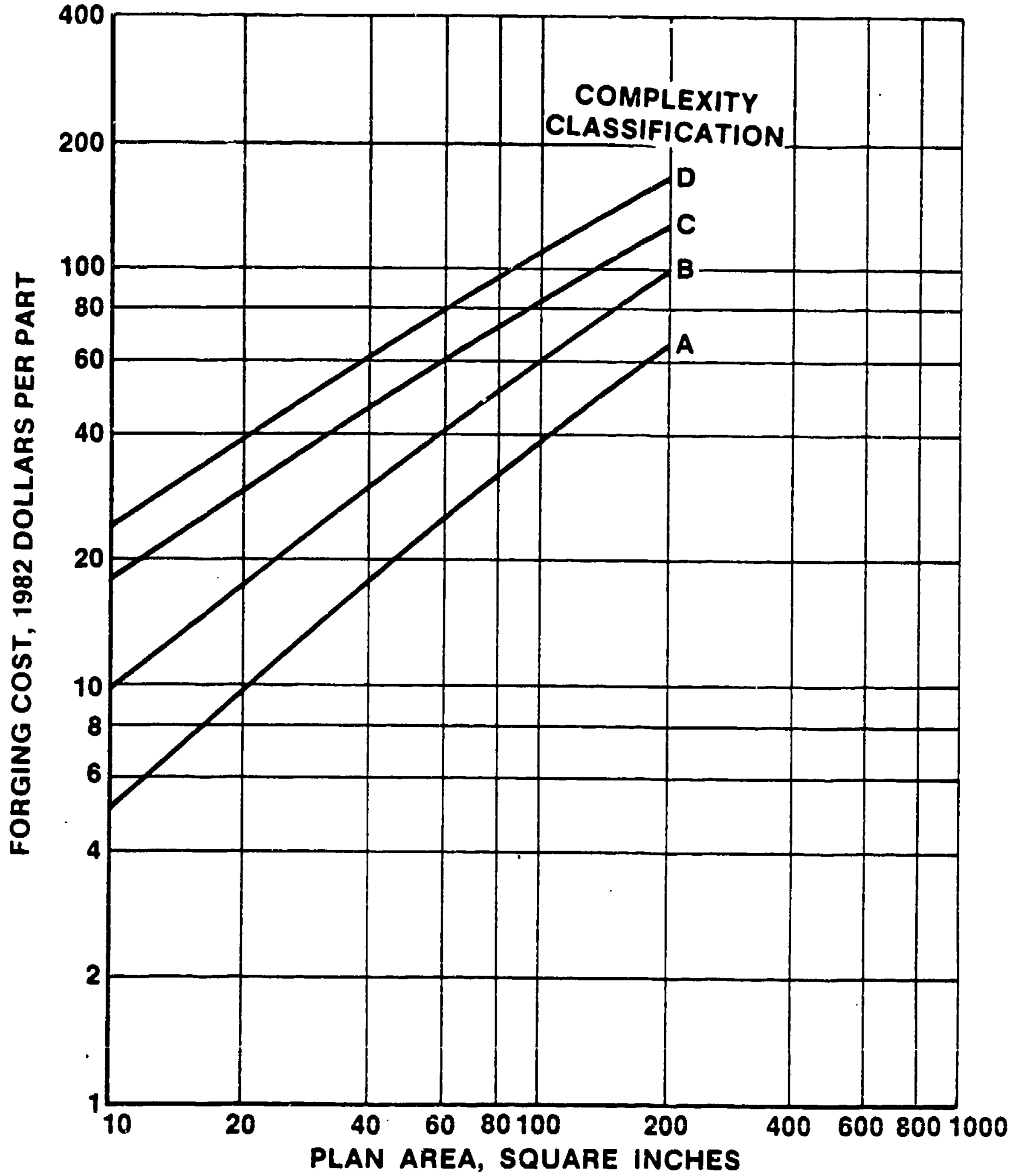
METHOD FACTORS

METHOD	FACTOR
BLOCKER	1.5
CONVENTIONAL WITH FLATBACK	1.5
CONVENTIONAL	3.0

NOTE: INFLATION FACTOR TO BE SUPPLIED BY INDIVIDUAL USER COMPANY.

CED-FC-10

ALUMINUM PRECISION FORGING BASE PART COST



CED-FP-1

ALUMINUM PRECISION FORGINGS QUANTITY FACTOR

ORDER QUANTITY	FACTOR
10 TO 25	1.6
26 TO 50	1.35
51 TO 100	1.2
101 TO 200	1.1
201 UP	1.0

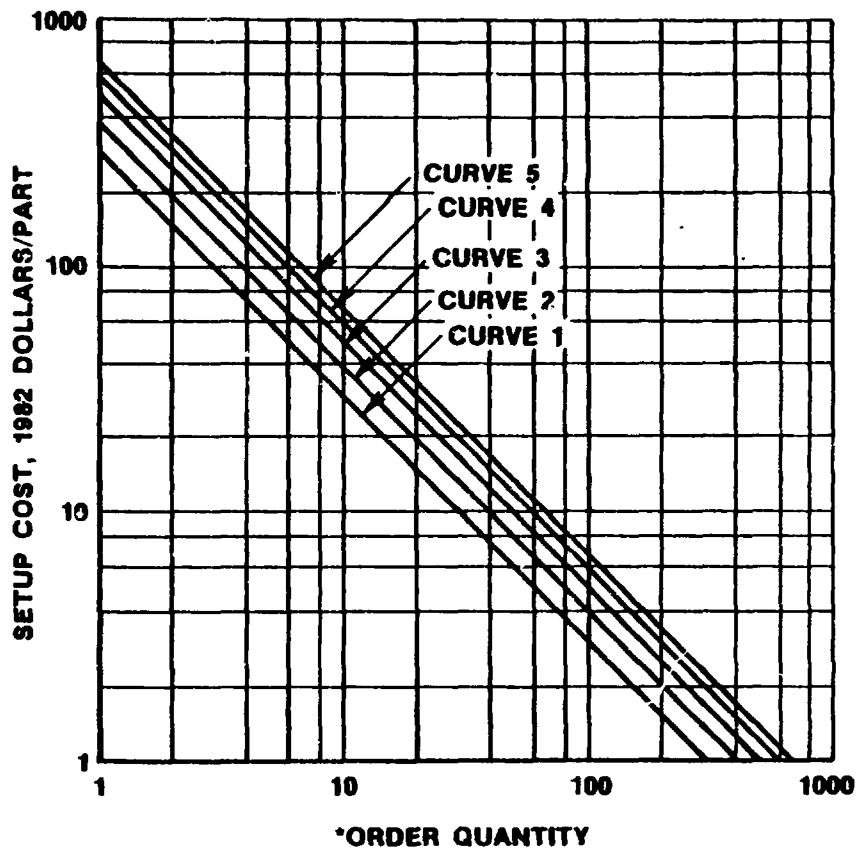
NOTE: IF ORDER QUANTITY IS NOT KNOWN, USE 1.35.

CED-FP-2

ALUMINUM PRECISION FORGINGS SETUP COST

CATEGORY	PLAN AREA	USE CURVE
A & B	UP TO 10 SQ. IN	1
A & B	11 TO 25 SQ. IN.	2
C & D	UP TO 10 SQ. IN.	2
A & B	26 TO 100 SQ. IN.	3
C & D	11 TO 25 SQ. IN.	3
A & B	101 & UP SQ. IN.	4
C & D	26 TO 100 SQ. IN.	4
C & D	101 & UP SQ. IN.	5

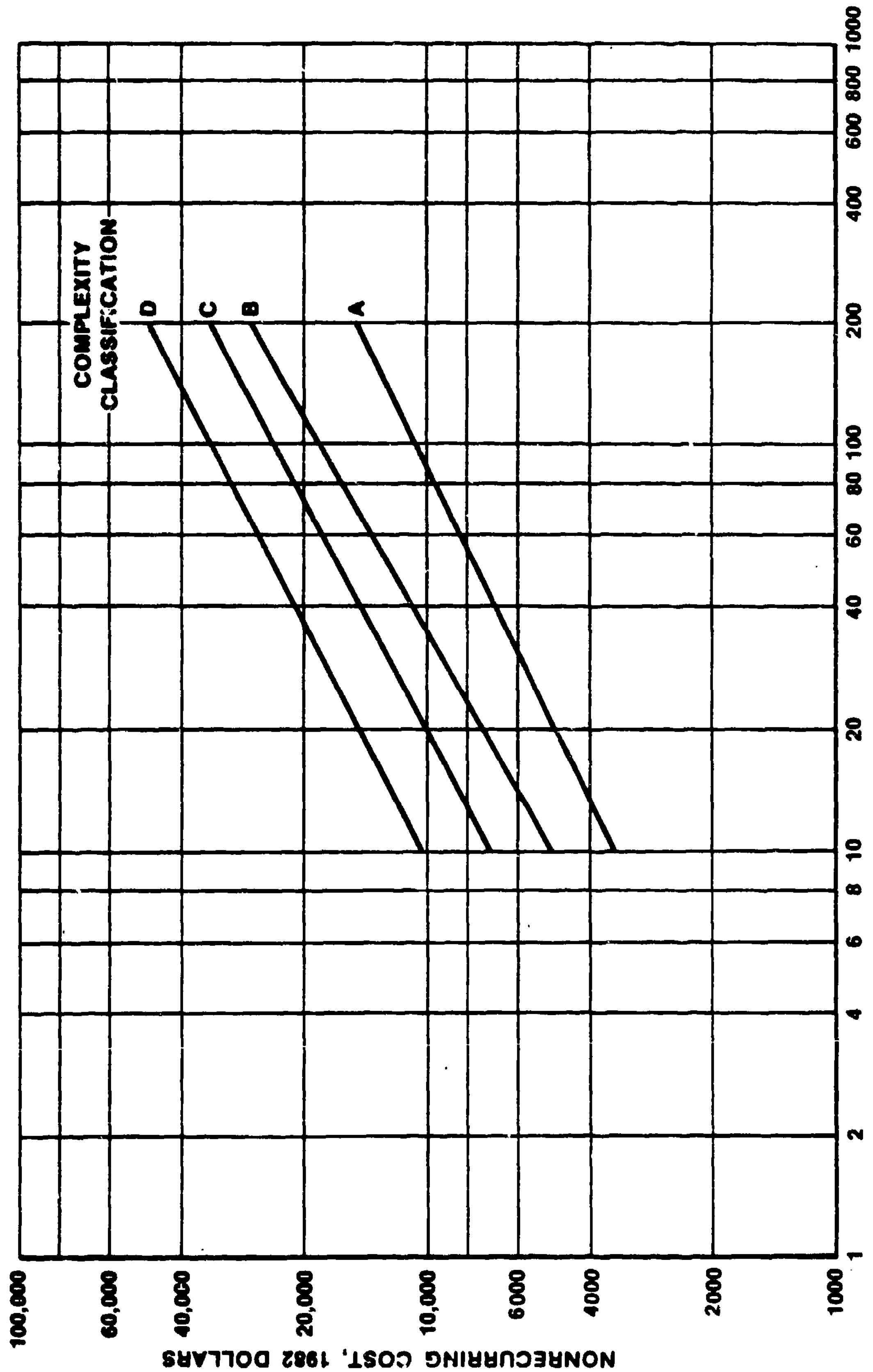
FORGING PRESS SETUP COST



*NOTE: IF ORDER QUANTITY IS NOT KNOWN, USE 50.

CED-FP-3

ALUMINUM PRECISION FORGING NONRECURRING TOOLING COST (NRTC)



CED-FP-4

ALUMINUM PRECISION FORGING RECURRING COST DICE FACTOR

DESIGN FEATURE		DICE FACTOR
WEB THICKNESS		
PLAN AREA	WEB THICKNESS	
UP TO 50 SQ. IN.	0.120	—
	0.090	1.3
51 TO 150 SQ. IN.	0.150	—
	0.120	1.3
151 TO 200 SQ. IN.	0.180	—
	0.150	1.3
RIB HEIGHT		
UP TO 1.50		—
1.51 TO 2.00		1.1
2.01 TO 3.00		1.2
3.01 TO 4.00		1.5
4.01 TO 5.00		1.7
5.01 TO 6.00		1.9
SPECIAL CONDITIONS		
LOFT CONTOUR		1.2
CYLINDRICAL CONTOUR		1.2
GRAIN DIRECTION		1.2
ANGLES OTHER THAN 90 DEGREE TO BASE		1.2

NOTE: IF MORE THAN ONE (1) DESIGN FEATURE IS APPLICABLE, USE ONLY THE HIGHEST.

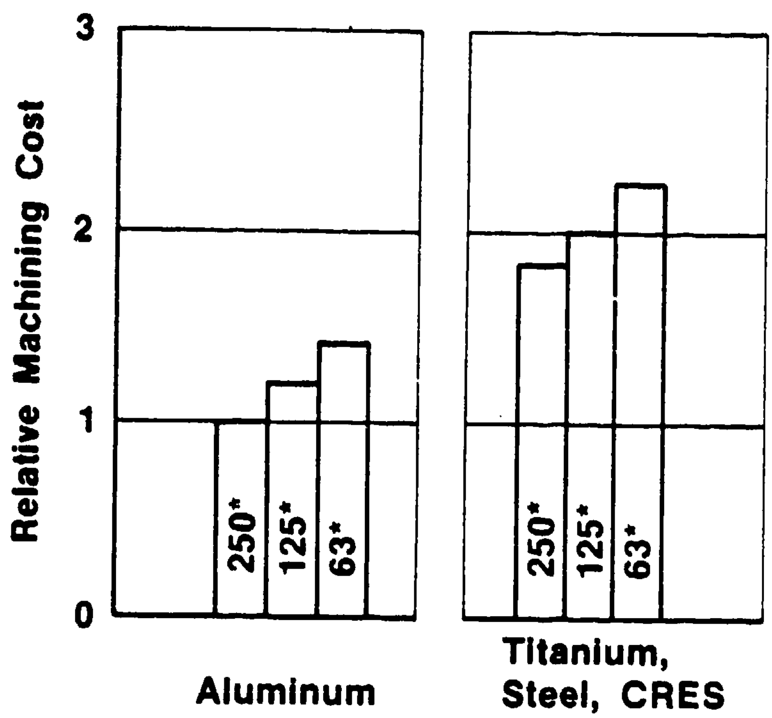
ALUMINUM PRECISION FORGING NONRECURRING COST DICE FACTOR

DESIGN FEATURE	DICE FACTOR
RIB HEIGHT	
UP TO 1.50	—
1.51 TO 2.00	1.05
2.01 TO 3.00	1.10
3.01 TO 4.00	1.25
4.01 TO 5.00	1.35
5.01 TO 6.00	1.45
LOFT CONTOUR	1.50

NOTE: IF MORE THAN (1) DESIGN FEATURE IS APPLICABLE USE ONLY THE HIGHEST.

DICE-FP-2

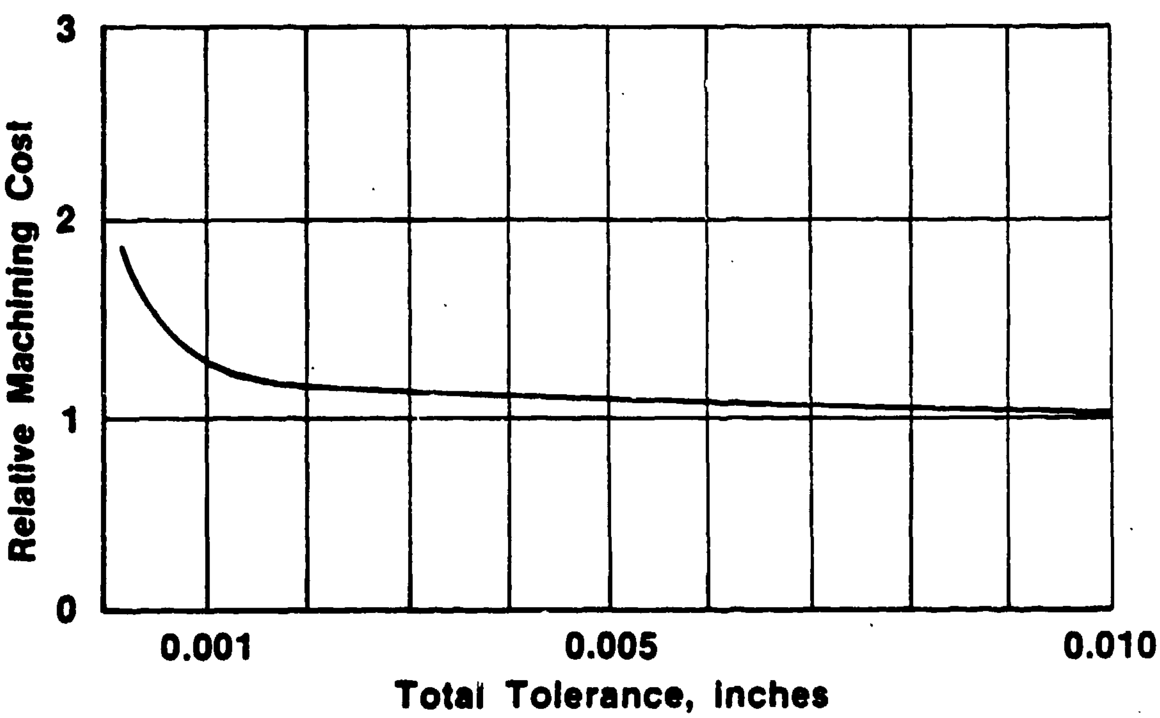
MACHINING OF FORGINGS
SURFACE FINISH
COST-DRIVER EFFECT



*Surface finish shown in micro-inches.

CDE-FM-I

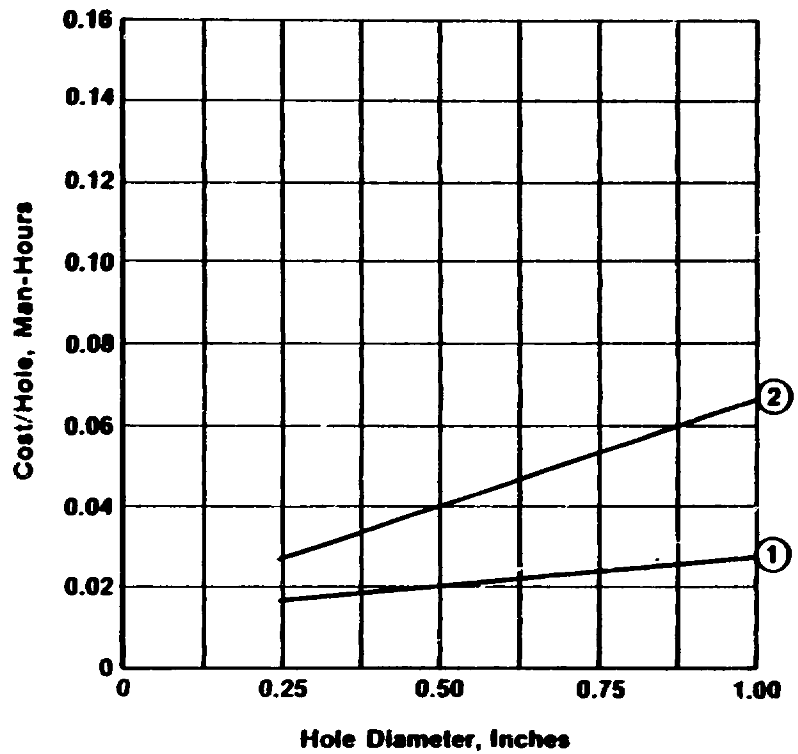
MACHINING OF FORGINGS— DIMENSIONAL TOLERANCES COST-DRIVER EFFECT



CDE-FM-II

MACHINING OF FORGINGS

DRILL HOLES



Nonrecurring Tool Cost

NRTC = (32 + 2N) Man-Hours

Where N is the number of holes in the pattern.

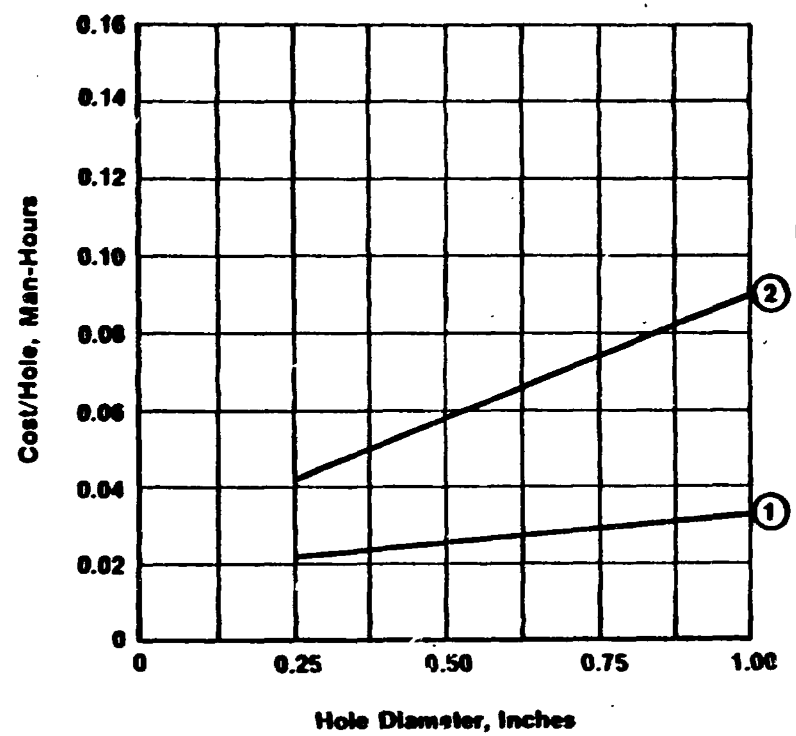
1 Aluminum
2 Titanium, Steel, CRES

Cost/Part = (Cost/Hole • N) Man-Hours

Cost data is valid for hole depths up to twice the hole diameter.

CED-FM-1

MACHINING OF FORGINGS
DRILL AND SPOTFACE HOLES



Nonrecurring Tool Cost

NRTC = (32 + 2N) Man-Hours

Where N is the number of holes in the pattern.

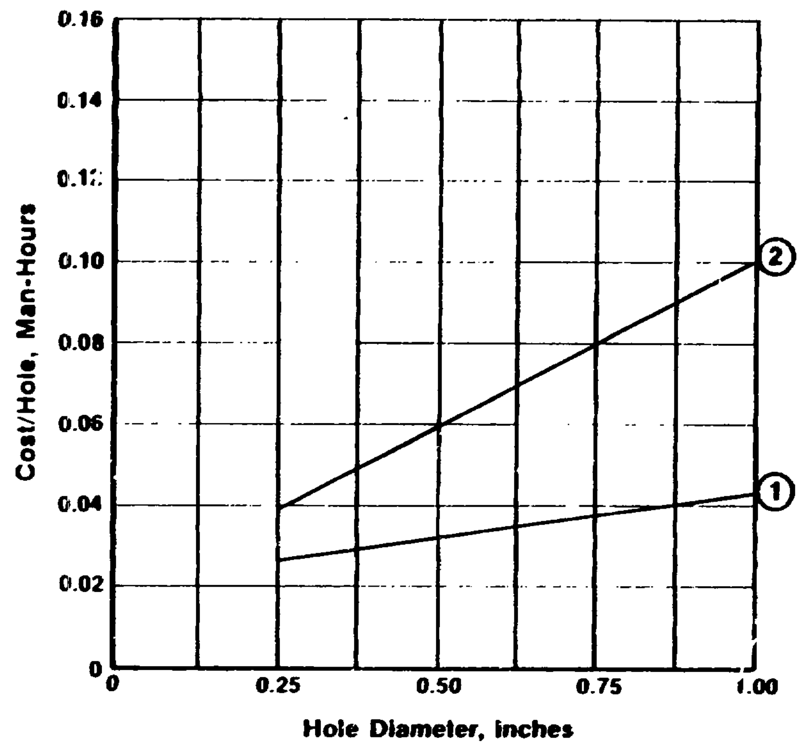
1. Aluminum
2. Titanium, Steel, CRES

Cost/Part = (Cost/Hole • N) Man-Hours

Cost data is valid for hole depths up to twice the hole diameter.

CED-FM-2

MACHINING OF FORGINGS
DRILL AND REAM HOLES



Nonrecurring Tool Cost

NRTC = (32 + 2N) Man-Hours

Where N is the number of holes in the pattern.

1 Aluminum

2 Titanium, Steel, CRES

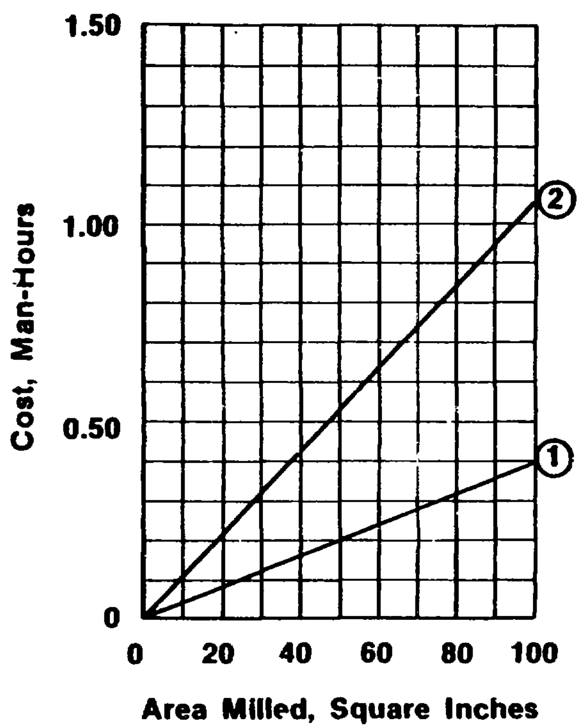
Cost/Part = (Cost/Hole • N) Man-Hours

Cost data is valid for hole depths up to twice the hole diameter.

CED-FM-3

MACHINING OF FORGINGS

FACE MILLING



Nonrecurring Tool Cost
NRTC = 57 Man-Hours

1. ALUMINUM
2. TITANIUM, STEEL, CRES

Step 1 — Determine the face milling cost for <u>each</u> surface machined.

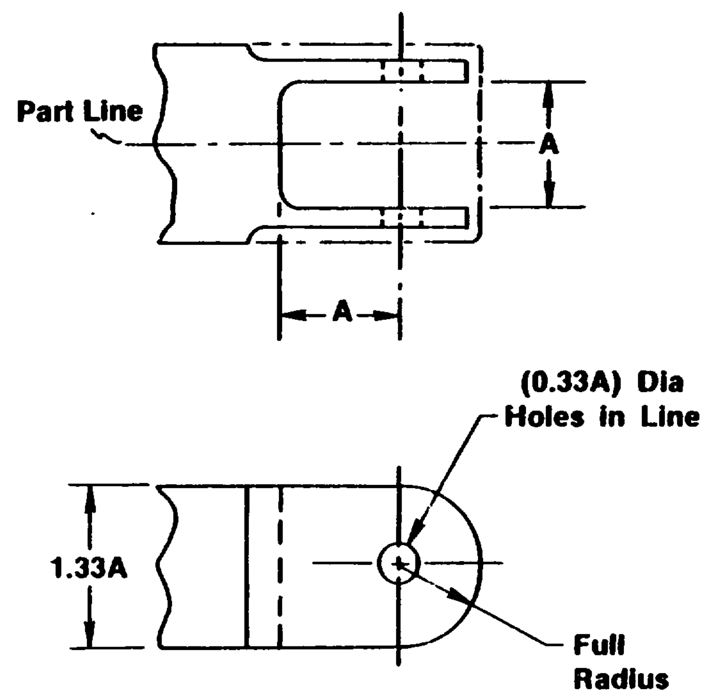
Step 2 — Add the milling costs obtained in Step 1.

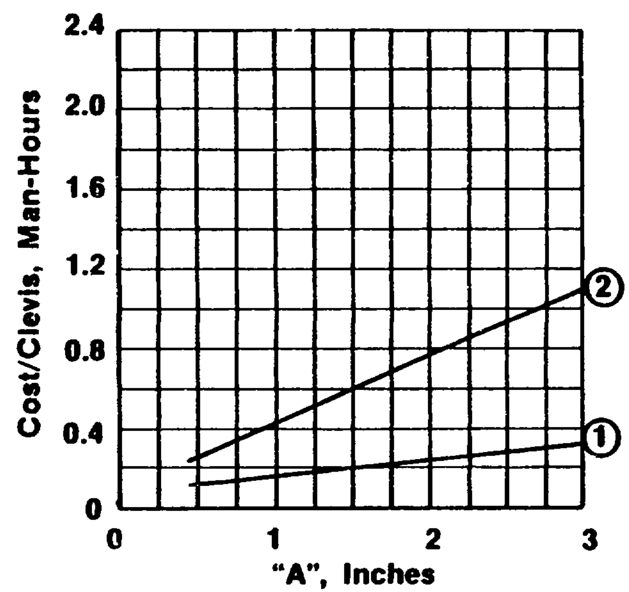
Step 3 — Obtain NRTC above.

CED-FM-4

MACHINING OF FORGINGS

STRADDLE MILL, DRILL & REAM





Nonrecurring Tool Cost
NRTC = (60 + 15N) Man-Hours

Where N is the number of clevises/part.

1 Aluminum

2 Titanium, Steel, CRES

CED-FM-5

4.6.5 Ground Rules for Forging Section

The following General and Detailed Ground Rules for the Forging Section were developed to establish the scope of the data required and to establish guidance to MC/DG application. Ground rules are necessary and important as they promote understanding, ensure consistency, uniformity, and accuracy in generating and integrating data into the formats.

4.6.5.1 General Ground Rules

The General Ground Rules are categorized under the following major groups:

(a) Forging Types
(b) Materials
(c) Forging and Applicable Machining (Limited)
(d) Machining
(e) Facilities
(f) Data Generation - Recurring Costs (including Forging TI&E)
(g) Forging TI&E Recurring Costs
(h) Data Generation - Nonrecurring Costs (including Forging TI&E)
(i) Support Function Modifiers
(j) Test and Evaluation of Data.

(a) Forging Types

(1) The forging types selected will be representative of parts commonly required for both small and large aircraft. The parts will be selected such that a base part forms the foundation from which the desired discrete part can be fabricated.
(2) The forgings will be selected, where possible, to develop data for more than one forging method. The data thereby enable the designer, using the MC/DG, to perform a trade-study to evolve the most cost-effective discrete part.
(3) The selected forgings will adequately display, by CED and CDE formats, the effect on cost of DICE.

(b) Materials

(1) The materials selected for the forged parts will be those commonly used in the industry to enable a uniform data base to be established. The materials included are:

- Aluminum
- Titanium
- Steel.

(c) Forgings and Machining

(1) Only conventional forging processes and TI&E methods will be considered. No emerging manufacturing methods will be evaluated.

(2) A production, in contrast to a prototype environment, will be assumed for the forged parts.

(3) To generate an effective data base for each selected part, a factory operational sequence utilized by the user will be established reflecting the most economical means of fabrication of the final part. This standardized sequence will be used by each team member to determine the part cost.

(d) Machining

(1) Limited machining data, as reflected in the MC/DG section on machining of castings, will be utilized for the forging section.

(e) Facilities

(1) Only standard manufacturing and TI&E facilities, will be considered.

(f) Data Generation - Recurring Costs

(1) Recurring cost data will be generated for the raw forging types being considered, and will include TI&E and mechanical property verification.

(2) Data will be generated separately for aluminum blocker, conventional, and precision forgings and titanium and steel blocker, and conventional forgings. Data to be based on plan area using historical data of the team airframe companies. Hand and ring forging cost methods will be developed.

(3) The DICE elements will be treated as separate cost elements, and therefore, not included in the base-part cost, but will be displayed using CED and CDE formats.

(4) In-house recurring tooling costs (tool maintenance, tool planning, etc.) will not be included.

(5) The quantity for which the base part and the DICE costs will be determined is at unit 200. A lot release size of 25 will be applied.

(6) The data submitted to BCL will be the raw forging part cost (dollars) plus the DICE incremental factors associated with the discrete forging design.

(7) In developing the cost data for parts, each participating company may utilize its own proprietary improvement curves.

(8) The base part and DICE costs will be normalized by BCL to reflect an industry average value.

(9) For proprietary reasons, business sensitive information employed at team member contributing companies to determine the data, will not be presented in the MC/DG.

(10) No data provided by any team member will be disclosed to other team members, agencies, or to the public without the expressed approval of the team member.

(g) Forging - TI&E Recurring Costs

(1) The applicable ground rules for data generation for forgings will be applied to the TI&E recurring cost.

(2) Recurring cost data will be generated for TI&E functions required from the supplier to receiving stores, including outside laboratories.

(3) TI&E cost data for the raw forging only will be included.

(4) Costs will be presented in 1982 dollars.

(5) CED and/or CDE formats will display the following TI&E costs and data, when applicable, to provide meaningful cost data to the designer:

- Penetrant Inspection
- Ultrasonic Inspection
- Magnetic Particle Inspection
- Mechanical Properties Verification
- Chemistry Verification
- Dimensional Inspection.

(6) TI&E cost data will be normalized by BCL to reflect an industry team average value.

(h) Data Generation - Nonrecurring Costs for Raw Forgings and TI&E

(1) Tooling costs will be generated for each part type. TI&E fixture costs will be the responsibility of the user company where applicable.

(2) The cost of production tooling will be restricted to contract or project tools only for presentation in the MC/DG.

(3) First article TI&E cost will be generated and displayed as part of the nonrecurring tooling cost.

(4) Nonrecurring tooling costs (NRTC) generated by the team companies will be normalized by BCL for presentation in the MC/DG.

(i) Support Function Modifiers

(1) Additional effort other than factory labor and TI&E, i.e., planning and tool maintenance, will be excluded from the part cost data supplied to BCL. Other modifiers may be included later by the MC/DG users at airframe companies.

(j) Test and Evaluation of Data

(1) Test and confirmation of the formats and integrated data will be accomplished by one of the MC/DG team members. Each of the remaining team members will be provided with the evaluation. Any anomalies will be resolved and modifications incorporated as appropriate.

4.6.5.2 Detailed Ground Rules

The detailed ground rules are categorized under the following major groups:

(a) Forging Types
(b) Materials
(c) Data Generation - Recurring Costs
(d) Data Generation - Nonrecurring Costs
(e) TI&E Functions

(a) Forging Types

(1) Each team member will review applicable forging designs and tabulate required data on the data collection sheets developed by the team.
(2) Selected typical designs will be utilized for determination of user-associated costs (e.g., machining).
(3) The forgings analyzed by each team member will be classified by material and type. This classification will be designated on the data collection form submitted to BCL. Each team member company will submit drawings or sketches to BCL illustrating their understanding of these forging types.

(b) Materials

(1) The materials and processes selected for the following forging types are:

- Aluminum
  - 7075 or equivalent hand, ring, blocker, conventional die, and precision forgings.

- Titanium
  - Ti-6Al-4V annealed hand, ring, blocker, and conventional forging.
- Steel
  - 4340 or equivalent hand, ring, blocker and conventional forging.

(c) Data Generation - Recurring Costs

(1) Data indicated on the data collection sheet will be gathered, as available, for the raw forging. TI&E costs associated with the raw forging will be established separately.

(2) Machining cost data previously developed for castings for the basic machining parameters listed below, will be reviewed for applicability to forgings. TI&E costs for the user operations will not be included as a part of this task.

(a) Counter-bore and face-hub

(b) Drilled holes, drilled and reamed holes, drilled and spot-faced holes

(c) Circular-flange facing (lathe), flat-faced (mill)

(d) Stradle-mill and drill-clevis fittings.

(d) Data generation - Nonrecurring Costs for Raw Forgings and TI&E

(1) Tooling costs will be generated for each part type. TI&E fixture costs will be the responsibility of the user company where applicable.

(e) TI&E Functions

(1) The following are typical TI&E operations that will be evaluated for cost impact:

- Chemistry

- Mechanical Properties
  - Separate test bars
  - Coupons from forgings (prolongation)
  - Dissected forgings
- Dimensional
- Ultrasonic
- Penetrant/Magnetic.

*USGPO: 1983-659-062-849